THE ROLE OF COFFEE BASED AGROFORESTRY SYSTEM IN WOODY SPECIES DIVERSITY CONSERVATION: THE CASE OF MANA DISTRICT, SOUTHWEST ETHIOPIA

M.Sc. THESIS

BY

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The Role of Coffee Based Agroforestry System in Woody Species Diversity Conservation: The Case of Mana District, Southwest Ethiopia

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Major advisor: Mr. Zerihun Kebebew
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I have incorporated the suggestion and modifications given during the internal thesis defense and got the approval of my advisers. Hence, I hereby kindly request the Department to allow me to submit my thesis for external defense.

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Decision /suggestion of department graduate council (DGC)

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Chair person, CGS Signature ___________________ Date _____/_____/______

DEDICATION

I dedicated to my wife, Fate Abdela and my sister Zahra Abazinab for their Love and dedicated partnership effort especially for their prayer in my academic success and life.

STATEMENT OF AUTHOR

First, I declare that this thesis is the result of my own work and that all sources or materials used for this thesis have been appropriately acknowledged. This thesis is submitted in partial fulfillment of the requirements for M.Sc. degree at Jimma University and to be made available at the University's Library under the rules of the Library. I confidently declare that this thesis has not been submitted to any other institutions anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

Abdo Abazinab Abajobir was born in Mana District, in Jimma zone of the Oromia Region State on September 1, in 1983. He attended his elementary and junior education in Haro Junior schools. He also attended his high school education in Yebu secondary school. After completion of his high school education, he joined Alage ATVT College to attend a three years Diploma program in Natural Resource. He received his BSc from Jimma University College of Agriculture and Veterinary Medicine in Natural Resource Management in June 2010. After graduation he was employed by Agricultural office (Agricultural agent), worked at various capacity. Abdo has got an opportunity to join the School of Graduate Studies at Jimma University to pursue his study leading to the Master of Science in Natural Resource Management (Forest and Nature Conservation).

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LIST OF ACRONYMS

CAF	Coffee Agroforests
CAFU	Coffee Agroforestry Users
CBD	Convention of Biological Diversity
CFCCE	Coffee Farming and Climate Change in Ethiopia
Cms	Centimeters
DBH	Diameter at Breast Height
EPRDF	Ethiopian Peoples' Revolutionary Democratic Front
FAOUN	Food and Agricultural Organization of the United Nations
FC	Forest Coffee
FFs	Forest Fragments
GC	Garden Coffee
GPS	Geographical Position System
Ha	Hectare
HHs	Households
IUCN	International Union for Conservation of Nature
IVI	Importance Value Index
KAO	Kebele Administration Office
Km	Kilometers
Masl	Meter above sea level
MDAO	Mana District of Agriculture office
NBSAP	National Biodiversity Strategy and Action Plan
NFU	Natural Forest Users
NTFP	Non-timber Forest Products
PC	Plantation/modern Coffee
SFC	Semi Forest Coffee
SPSS	Statistical Package for Social Sciences Software
Ss	Sorensen's similarity index

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ABSTRACT

Conversion of forest to agriculture has already been taking place in southwest Ethiopia. Many of biodiversity are conserved in agricultural landscapes. In the long-term conservation of native species, highly depends on agricultural landscapes. Coffee agroforestry has been promoted as a means for preserving biodiversity in the tropics. The study was conducted to assess woody species composition, diversity, regeneration, and forest resource utilization of coffee agroforestry and natural forest at Mana district, Southwest Ethiopia. Vegetation data were collected from coffee agroforestry and natural forest. In coffee agroforestry, 30 plots were laid in coffee agroforestry at the center of coffee farms based on observation (one plot per household farm). Similarly in natural forest, 30 plots were laid along transect at a distance of 100 m between each transects lines and plots. A total of 60 plots of 20 m x 20 m for trees, 10 m x 10 m for saplings and 5 m x 5m for seedlings were laid for vegetation data collection. Household interview was conducted to collect forest resource utilization between coffee agroforestry users and natural forest users. A total of 60 sample households (30 households for each land uses) were randomly selected for the interview. The collected vegetation data were tested by independent t-test and forest resource utilization data were analyzed descriptively using Microsoft Excel and the Statistical Package for Social Sciences (SPSS) version 20. The vegetation data results showed that a total of 25 woody species belong to 20 families in coffee agroforestry and 30 woody species belonging to 23 families in natural forest were identified and recorded. Although more woody species were recorded under the natural forest, the difference was not statistical significant ($p>0.05$) between coffee agroforestry and natural forest. Regeneration status of seedlings and sapling of the woody species indicated significant ($P < 0.05$) differences between coffee agroforestry and natural forest. This showed that natural forests have higher regeneration status than coffee agroforests. However, the mean density of woody in coffee agroforests and natural forest show no statistically difference ($p > 0.05$).Forest resource utilization result shows that coffee agroforestry users were creates an opportunity to obtain forest resource utilizing from their own coffee form. The natural forest resources were accessible to any community member because lack of enforcement of the rules that protect the forests. Consequently, there is forest degradation due to deforestation and illegal harvesting. Coffee agroforestry contributes to conservation of woody species through retention of woody species on the farm and reducing pressure on the natural forest, which may contribute to conservation of woody species. Therefore, conservation of woody species and forest resource utilization must be linked in the arena of conservation approaches.

Key words: Woody Species Diversity, Community Structure, Regeneration and Forest Resource Utilization

1. INTRODUCTION

1.1. Background

Southwest Ethiopia is coffee growing region. Most of natural forest in the area modified to coffee agroforestry (Aerts *et al*., 2011). Hence, conservation of biodiversity depends on management of coffee agroforestry. The forest is home to Arabica coffee supporting diverse species and recognized as one of biodiversity hotspot areas (Tadesse *et al*., 2014). Due to the abundance of coffee and other major non-timber forest products (NTFPs), the forest has a key role in generating income and supporting millions of households (Labouisse *et al*., 2008; Melaku *et al*., 2014). Nevertheless, these important forest resources have been under continuous change as results of the intensification of coffee production (Schmitt *et al*., 2009; Tadesse *et al*., 2014). The once natural forest is modified to coffee agroforestry that are mainly produced by smallholder farmers' (Aerts *et al*., 2011).

Despite forest modification, many indigenous tree species are retained in coffee agroforestry and has attracted much attention for woody species conservation (Tadesse *et al*., 2014). Study by Molla and Kessew (2015) has shown that traditional agroforestry has significant contribution in conservation of native tree species. In southwest Ethiopia, compared to large coffee plantation more woody species have been retained in smallholder coffee farm (Tadesse *et al*., 2014). Research depicts coffee agroforestry can reduce a pressure on the remaining natural forest as a buffer zone. The natural forest is said to be a natural capital. Coffee agroforestry is a means of natural forest exploitation to produce more goods and services to the society. As a result, ecosystem goods and services obviously vary from undisturbed natural forests to intensively managed or modified by agricultural land (Fisher *et al*., 2009).

Nevertheless, coffee agroforestry is said to conserve high biodiversity and offer much greater conservation value (Komar, 2006). For instances, shaded coffee production system has received considerable attention from conservation organizations in recent years in which it supports biodiversity and cash income generation from the sale of forest products (Gordon *et al*., 2007). Coffee is the understory of the forest and many woody species are conserved together with shade tree in coffee production under shade (Stills *et al*., 2012).

There is high pressure on the natural forest, mainly for agriculture expansion, settlement and plantations (Gole *et al*., 2008). Studies have demonstrated unparalleled dramatic human influences on the forest (Didita *et al*., 2010). Different scholars and environmental experts have different views on how to protect and conserve biodiversity (Sunderland *et al*., 2008). Many findings have supported coffee agroforestry not only in terms of the ecosystem services it provides but also many coffee farms are nearby or adjacent to the natural forest (Moguel and Toledo, 1999). As a result, ecological services provided by shade coffee production has generated much attention from different perspective towards addressing conservation of biodiversity loss (Reichhuber and Requate, 2012).

Understanding the relationship between tree species diversity, vegetation structure and forest resource utilization can provide insight on how these resources can be used to support both conservation and household livelihood strategies (Bacon *et al*., 2008; Gomez-Baggethun *et al*., 2010). Conversion of forest in to various other land use systems has serious impacts on distribution, community structure and population characteristics of vegetation and high threatening availability of forest products. An integrated landscape approach has been suggested in conservation of biodiversity, provision of ecosystem services, and sustaining the rural livelihoods (Tscharntke *et al*., 2012). Forest biodiversity is disappearing rapidly in the forest landscapes (Senbeta and Denich, 2006). The spatial pattern of biodiversity is crucial to assess the consequences of forest degradation and habitat loss caused by human activities and to develop systematic conservation strategies (Fjeldsa, 2007). Therefore, the current study was intended to assess the role of coffee based agroforestry system in woody species diversity conservation: the case of Mana District, Southwest Ethiopia.

1.2. Statement of the Problem

The loss of biological diversity is happening worldwide at alarming rates and is predicted to increase due to climate change (Rockström *et al.*, 2009). A major driver of biodiversity loss in the tropics is conversion of forest to agricultural land and agricultural intensification (Tscharntke *et al*., 2011). The extent of past forest cover on the Ethiopian highlands is evident from the numerous isolated mature forest trees or small patches of forests or woodlands that make obvious landmarks on the plateau (Friis, 1992). Large areas with evergreen bush land or farmland mixed with bush land represent formerly forested areas (Friis, 1992).

The role of forests and forest products to household food security and to the national economy is indispensable. However, deforestation has already affected the lives of many in the target area. This has resulted in environmental problems such as forest biomass reduction, decline in the productivity of the land, soil erosion, and loss of biodiversity which subsequently led to frequent socio economic problems. Many of the socioeconomic problems in the country in general and in the study area in particular are associated with deforestation and misuse of land. Alteration of forest habitat through grazing and expansion of agriculture could not only lead to decline in local biodiversity but also affects food security of local communities as many people are directly or indirectly dependent on forest and forest related activities.

Previous studies in Mana District, southwest Ethiopia have focused on shade tree selection and management by farmers in traditional coffee production systems (Hundera, 2016), characterizations of the trees Diversity in the agro-forests of coffee (Mahmood, 2008) and The Impact of Farm Tree Degradation on Rural Livelihood (Bajigo and Abraham, 2017). Some findings have shown that modifying the natural forest for coffee production has reduced the floristic diversity and specific functional groups (Tahir M., 2008). Converting natural forest to different agroforestry systems has some drawbacks. However, the role of coffee based agroforestry in woody species diversity; vegetation conservation, regeneration status, forest resource utilization and access and reducing pressure on the natural forest are less studied. Therefore, this study was aimed at provide relevant information, which is most importance to undertake on diverse range of economic, ecological information about the coffee agroforestry and natural forest to design suitable conservation and sustainable use approaches. In addition, provide information about forest product utilization between coffee agroforestry users and natural forest users.

1.3. Objective

1.3.1. General objective

To assess the role of coffee agroforestry in woody species conservation and forest resources utilization

1.3.2. Specific objectives

1. To compare woody species composition and diversity under coffee agroforestry and natural forest.
2. To compare structure and regeneration status between coffee agroforestry and natural forest.
3. To assess forest resource utilization between coffee agroforestry and natural forest with respect to human activities in the study area.

1.4. Research questions

1. Is there dissimilarity in woody species composition and diversity between a coffee based agroforestry and natural forest?
2. Is there a difference in structure and regeneration status between coffee based agroforestry and natural forest?
3. Does forest resource utilization differ between coffee based agroforestry and natural forest?

2. LITERATURE REVIEW

2.1. Definitions and Concepts of Agroforestry

Several definition of the term "agroforestry" is used in the literature. As per Leakey (1996), agroforestry is "a dynamic ecological based, natural resource management system that, through the integration of trees on farms and in the landscape, diversifies and sustains production for increased social, economic and ecological benefits"

2.2. Biodiversity Conservation

Biodiversity is used to convey the total number, variety and variability of living organisms and the ecological complexes in which they occur (Rosenzweig, 1995) while floristic biodiversity is referred to the number, variety and variability of the flora. Also incorporates human cultural diversity, which can be affected by the same drivers as biodiversity and which has impacts on the diversity of genes, other species and ecosystems (Buscher and Whande, 2007). Biodiversity rich habitats will be lost or degraded, especially in the tropics, and the distribution and abundance of species and ecosystems will change dramatically (Leadley, 2010).

Loss of forest biodiversity diminished forest ecosystems‟ resilience, their ability to adapt and recover from natural and human induced disturbance. Societal changes those associated with increasing wealth and consumption, further intensify pressures on forests (Haines-Young, 2009). Forest biodiversity loss continues to occur disproportionately since the highest levels of deforestation and forest degradation reported for biodiversity-rich natural forests in developing countries (Pereira *et al*., 2010). Ethiopians are facing rapid deforestation and degradation of resources. It indicated that the forest cover shows a declined from 15.11 million ha in 1990 to 12.2 million ha in 2010, during which 2.65% of the forest cover deforested. Consequently, deforestation and forest degradation continued unabated at an annual rate of about 2% about 700,000 ha of forests destroyed every year (Moges *et al*., 2010).

The forest areas are declining partly through logging activities and due to conversion of habitats to agricultural expansion accounts for up to 40 percent of forest losses (Winberg, 2010). Contrary to the decline in forest resources, the population depends heavily on wood (Duguma *et al*., 2009). Clearance of natural vegetation to meet the demands of an ever-increasing human population has been an ongoing process because of increasing demand for agricultural land and firewood and charcoal (Soromessa *et al*., 2004). Most of the remaining natural high forests found in the southwest of Ethiopia, which was remote and inaccessible until recently. The estimated three regions containing that highest forest Oromia National Regional State, SNNPR and Gambela about 1.24 million ha of natural high forests are cleared for agricultural expansion 1990-2014. This amounts to a loss of a third of the 1990 high forest resources in the regions (Bekele *et al*., 2015).

The integration of local land use and biodiversity conservation through community based forest management or the promotion of environmentally friendly agricultural practices (Scherr and McNeely, 2005). Common insights and principles improve forest biodiversity conservation in a variety of landscapes and land uses (Lindenmayer and Hunter, 2010). They include better understanding landscape mosaics and forest remnants; connectivity across landscape gradients and between remnants; the variable responses of individual species to disturbances; and the roles of various forms of planted forests in biodiversity conservation. Better approaches to conceiving, planning and managing land use change implemented (Pfund, 2010). Concentration on individual species and particular land uses to recognize interdependencies between ecosystems and human populations (Bond and Parr, 2010). Conservation approach builds alliances between ecologically sustainable agriculture and existing conservation efforts to manage human-modified landscapes to enhance biodiversity conservation and promote sustainable livelihoods (Harvey *et al*., 2008; Chazdon *et al*., 2009).The extent of natural forest maintained in a human-modified landscape primarily determines species richness (Gardner *et al*., 2010). The key drivers of forest biodiversity loss are population and consumption growth; increasing trade in food and agricultural products; growing demand for forest products, including biomass for energy generation; expansion of human settlements and infrastructure; and climate change (DeFries *et al*., 2010).

In the past, biodiversity conservation has been mostly understood in terms of the management of natural forests and protected areas, ignoring the possible role of managed habitats and the ways through which rural communities have promoted biodiversity in their subsistence agricultural production systems (Perfecto *et al*., 1996). However, currently it is well recognized that biodiversity is not an issue only within forests, parks and other unmanaged/natural ecosystems but also within agroecosystems (Atta-Krah *et al*., 2004, Swallow *et al*., 2006). Agricultural biodiversity includes all the components of biological diversity relevant to food and agriculture such as crops, trees, fish and livestock, and all interacting species of pollinators, symbiots, pests, parasites, predators and competitors (Atta-Krah *et al.*, 2004). As it incorporates additional species (trees and shrubs) into agriculture, an agroforests ecosystem contributes to agricultural biodiversity and provides a refuge for forest dwelling organisms. One such agroecosystems is a traditional coffee production system. In the last decades, numerous investigations (e.g., Méndez 2004, Jha and Vandermeer 2010, Méndez *et al*., 2010, De Souza *et al*., 2012), particularly in Central and South America, have shown the biodiversity conservation potentials of coffee agroecosystems.

2.3. Coffee Growing System

Coffee cultivation systems around the world fall along a continuum, ranging from nearly-wild conditions through “traditional” to “modern”. The “wild” (“forest” coffee) system is a growing of coffee in a forest ecosystem with no or minimal management. The traditional system is characterized by high shade cover (60-90%), low coffee density (1,000-2,000 plants/ha) and low levels of management. The modern system is characterized by a high reliance on high-yielding varieties with dense planting (3,000-10,000 plants/ha), chemical inputs, mechanizations and low levels (0-50%) of shade (Perfecto *et al*., 1996).

In Ethiopia, there are four major coffee production systems. These include forest coffee (FC), “semi forest coffee” coffee (SFC), garden coffee (GC) and plantation/modern coffee (PC), each respectively accounting for 10%, 35%, 35% and 15% of the total national coffee production (Senbeta 2006). The first two systems are dominant in SW Ethiopia and the modern commercial plantation coffee is also found in this region. The garden coffee production system is mainly dominated in the southern, south-eastern and eastern parts of the country.

The intensity of management varies from little or no interventions in FC to high use of improved varieties, chemical inputs and pruning's in PC. FC and SFC are regarded as part of the forest coffee ecosystems and they occupy 33% of the land given for coffee (Senbeta 2006). FC is a production system where coffee berries are simply picked from naturally growing (wild) coffees in the natural forest without any management. SFC is evolved from natural forest coffee by thinning out the small trees and shrubs competing with coffee in the lower storey and the large trees in the upper storey. It may also have evolved from planted coffee under the selectively thinned tree canopies of the existing natural forests. The latter is given a different name by different researchers, e.g., SFC- plantation (Gole 2003), semi-plantation coffee (SPC) (Hundera *et al*., 2013a); hereafter SPC is used for this system. Thinning of shade tree canopies and removal of other competing plants are the main management activities in SFC system. In GC system, coffee is grown with many other crops, particularly horticulture crops, e.g., "enset" fruits, spices, etc. It is often managed in the area surrounding the farmer's home. PC growing under shad trees that selectively retained from natural forests on a large-scale by private coffee farmers (investors) or the state. The intensity of management practices, such as weeding, pruning, fertilization, thinning and other silviculture practices is higher in PC compared to the other systems.

2.4. Coffee Based Agroforestry System

In many tropical landscapes, agroforestry systems are the major ecosystems that resemble natural forest (Bhagwat *et al*., 2008). Human activity has led to the modification of increasingly large tracts of the terrestrial biosphere, with estimates ranging up to 40% of the total area (Foley *et al*., 2005). According to Schroth *et al*., (2004) mention three ways in which agroforestry practices can contribute to biodiversity conservation: (i) they may decrease the pressure on the natural forest; (ii) they provide a habitat for forest species; and (iii) they help to create a biodiversity friendly landscape mosaic. They can provide landscape diversity and heterogeneity that can further increase matrix quality for the biodiversity in forest fragments (Gardner *et al*., 2009). The potentials and challenges of biodiversity persistence in coffee agroforestry provide useful information about the balances and interactions associated with integrating wild biodiversity conservation with agricultural production (Power, 2010). These systems potentially have enhanced both rural livelihoods, high biodiversity conservation value; protection of pristine habitat needs with such environmentally friendly and sustainable land use systems (Perfecto *et al*., 2007). Shaded coffee plantations are increasingly valued for their contributions to biodiversity conservation and ecosystem services (De Beenhouwer *et al*., 2013).

Most of different work provides lines of evidence in support of shaded agroforestry: it is vital in biodiversity conservation and diversifying farming systems (Rice, 2008). It is not only provides provisioning services but also diversification of household income to local communities. Coffee agroforestry systems can potentially (1) protect biodiversity by providing heterogeneous and critical habitats, (2) buffer against overexploitation of forest biodiversity, and (3) serve as corridors and permeable matrices that connect communities in natural landscapes (Perfecto *et al*., 1996).

Coffee-growing areas fall largely within areas identified as biodiversity hotspots (Donald 2004), which are areas featuring exceptional concentrations of endemic species and experiencing exceptional loss of habitat (Myers *et al*., 2000). Most coffee production in many regions including Southwest Ethiopia is undertaken on lands that were formerly under forest, so it has historically been a cause of deforestation. For instance, coffee plantations in Central and South America make up some 54% of the permanent cropland that have replaced the cloud and pre montane rainforests (Donald 2004). However, in many areas that have suffered from severe deforestation, shade coffee systems may now represent an important refuge for forest biota, especially for non-specialist taxa (Perfecto *et al*., 1996). This fact has been elaborated further in the next few paragraphs via a number of research results.

In Brazilian rainforest region, De Souza *et al*. (2012) identified a total of 231 tree species, 87 in the agroforests (AFs) and 178 in the forest fragments (FFs). The tree species richness ranged from 15 to 41 species and 12 to 20 families in the individual AFs, and from 54 to 70 species and 24 to 28 families in the FFs. Overall, 38% of the tree species (33 species) that were present at least in one of the AFs also occurred at least in one of the FFs, and both systems shared 13% of the total of number of species. In Nicaragua and El Salvador, households managed 100 shade tree and epiphyte species, food crops and medicinal plants in small-scale coffee farms (Méndez *et al*., 2010). A review by Méndez (2004) showed a range of 90 to 120 native tree species in rustic coffee agro ecosystems of Mexico and 19 to 77 tree species in Costa Rica, Nicaragua and El Salvador. Coffee farms and forests in El Salvador shared 16% of the total (227) tree species identified. Peruvian farmers reported an average of eight tree species in their coffee areas, with 135 total individuals/ha, but Guatemalan growers make use of four distinct trees, with 163 total individuals/ha. Totally, 62 species reported by growers in Guatemala and 77 species in Peru (Rice 2008). In Guine´e Forestie`re, Guinea, Correia *et al*., (2010) reported higher tree species richness and diversity in the coffee agroforests than in any other agricultural or agroforestry land-use systems, but significantly lower than in the natural forests. Several studies (e.g., Perfecto *et al*., 1996, Gordon *et al*., 2007) in the region of Central and South America also reported that a number of arthropod, insect, mammal and bird species is living in the various types of coffee agro ecosystems. However, their diversity incrementally reduced as a forest ecosystem transformed into a shade coffee, and a shade tree density and cover decreased or as management intensity increased (Méndez 2004). Perfecto *et al*., (1996) indicated similar or higher diversity of arthropods in the shaded coffees compared to in the undisturbed forests.

Outside Central and South America, however, quantitative studies dealing with biodiversity in the CAFs are very limited. In Ethiopia, there are a few studies that have directly analyzed the potentials of a CAF ecosystem to biodiversity conservation. In Southwest and Southeast Ethiopia where natural forest coffee is found, some studies analyzed the impacts of humans on natural forests with wild coffee (forest coffees) and managed forests ("semi-forest" coffee). These include the studies by Gole (2003), Senbeta (2006), Schmitt (2006) and Hundera *et al*., (2013a). They compared the floristic composition and diversity of FC and SFC in Yayu (Illubabor Zone), in Berhane-Kontir (Bench-Maji Zone) and Harenna (Bale Zone), in Bonga (Kaffa Zone), and in Gera, Garuke and Feche (Jimma Zone), respectively. In all study areas, the number of woody species (except Harenna and Bonga) as well as Shannon diversity and evenness was higher in FC than in SFC. At Harenna and Bonga, however, the variations in floristic composition between the two systems were very low. For example, total woody species in FC and SFC at Harenna and Bonga was 137 and 121, and 95 and 96, respectively.

There was also no statistical difference between FC and SFC at Berhane-Kontir in terms of big canopy and medium trees, herbs and epiphytes. Similarly, the difference between FC and SFC in diversity and community composition at Gera, Garuke and Feche was not statistically significant, but there was a difference between FC and SPC (Hundera *et al*., 2013a). In addition, there were variations within SFC systems and diversity was decreased with duration and the intensity of management (Gole 2003). For example, the SFC-new was significantly different from SFC-old and SPC in terms of mean number of species per plot.

2.4.1. Woody species conservation

Coffee is traditionally grown in the understory of shade trees, and agroecosystems of shaded coffee preserve the forest and provide an important refuge for biodiversity (Buechley *et al*., 2015). A number of studies have argued that the similarity of the vegetation structure in traditional shade coffee plantations to that in native forests remnants makes agroecosystems an important component of strategies for conserving tropical montane biodiversity (Moguel and Toledo, 1999). Semi-domesticated species in agroforestry systems frequently maintain high levels of species diversity (Dawson *et al*., 2013). Higher woody biodiversity maintained in individually managed small-farms compared to collectively managed cooperatives in Central America (Mendez *et al*., 2010).

Coffee in agroforestry systems occurs in Ethiopia and cultivated under shade of remnant native trees (Muleta *et al*., 2008). Traditional coffee agroforests have been established mostly from the original forest vegetation through minimal management (understory clearings), or by active management and eventual diversification of shade tree species (Senbeta and Denich, 2006; Hylander *et al*., 2013). Forest and agroforests interactions in southwest Ethiopia for ecosystem services might have contributed to the conservation of forest fragments and the maintenance of diverse native species in coffee agroforests (Hylander *et al*., 2013).

Smallholder semi-forest coffee species diverse as a result of keeping these species for diverse purposes, due to minimum management and input by coffee growers (Hundera *et al*., 2013). Smallholder farms were almost like forests in structural and life form diversity, and had species that are more native and regeneration. This implies a relatively high functional diversity that supports more species and ecosystem services (Tadesse *et al*., 2014). Therefore, conservation of the last remnants forests contains a genetic reservoir for coffee is of high priority (Silvestrini *et al*., 2007). Most of local people depend on coffee agroforestry for ecosystem services and goods such as coffee, spices, forest honey, and fodder (Schmitt *et al*., 2010).

Depending on their origin and management, there are variations among CAFs both in vertical and horizontal vegetation structures. Various research results in Southwest Ethiopia (e.g., Gole 2003, Senbeta and Denich 2006, Schmitt 2006, Hundera *et al*., 2013a) showed variations between FC and SFC systems (with some exceptions) as well as within SFC systems in density, basal area, canopy cover and population distribution based on dbh, height or age classes of coffee and non-coffee woody plants.

Based on shade tree canopy, Mahmood (2008) identified two types of coffee agroforests in Haro area, Jimma Zone: (1) mixed tree canopy type and (2) *Acacia* and *Albizia* (A+A) dominated type. The former contains 2-3 canopy layers and the latter 2 canopy layers. The upper layer in A+A comprises *Acacia* or *Albizia* while the second layer comprises coffee. Whereas in mixed canopy type, big and old trees, such as *Prunus africana*, *Trichilia emetica*, and *Croton macrosatychus* form the first upper layer, young planted or regenerated *Croton macrosatychus, Cordia africana* and sometimes *Albizia sp* the second layer, and coffee the third lower layer.

The findings of all these studies confirmed that CAFs retain many forest species that play a key role in the conservation of regional forest tree diversity. However, its plant species diversity and composition as well as vegetation structure are highly affected by the intensity of coffee management. Furthermore, most of the studies in Southwest Ethiopia have compared SFC systems with FC system, but there is a lack of studies that compared PC system with both SFC and FC systems. In this regard, the results of this research will have a good contribution to fill this knowledge gap.

2.4.2. Socio-economic benefits

Diversifications of crops enhance ecological resilience, diversity livelihoods and economic benefits for coffee producers (Rice, 2008). Diversity of crops and shade trees provides farmers with alternative income sources in cases of crop losses and price fluctuations; income across the growing season; food for home consumption; and improved fertilization. Therefore, the services and products provided by shade trees and additional crops in addition to coffee yields when evaluating diversified farming approaches (Jha *et al*., 2014). Individually, managed farms adopted vegetation diversification in order to generate a wider variety of tree products and on-farm benefits (Mendez *et al*., 2010). Farmers managed coffee plantations for both household consumption products and income from coffee and challenge of distributing and benefits to obtain more on-farm products (Mendez *et al*., 2009).

Coffee grown under the shade of or in association with native forest trees, sustain rural livelihoods and support high amounts of biodiversity (Schroth *et al*., 2004). Shaded coffee production system has received considerable attention from conservation organizations in recent years in which it supports cash income generation from the sale of both timber and non- timber forest products (Gordon *et al*., 2007). Evidence suggests that NTFPs “ensuring food security, providing cash income, livelihood security and diversification” (Shackleton and Gumbo, 2010). NTFPs to rural households in a comparative analysis of the literature found that: 1) NTFPs are widely accessible and crucial to the rural poor, 2) harvesting NTFPs less ecologically harmful than timber harvesting, and 3) as NTFPs become more valuable, local harvester are incentivized to conserve resources to sustain the supply and future income earnings (Belcher *et al*., 2005).

The local communities living in and around the forest mainly derive their livelihoods from coffee forests which are the source of timber and non-timber forest products like honey, spices, wild food, medicine (Senbeta, 2006). According to Gardei (2006), the majority of farming communities in Southwest Ethiopia are forest dependents and major source of their livelihood and subsistence by providing variety of forest products. According to the study, more than 65 percent of the households who were involved in NTFPs did earn more than one thousand Birr in a year from the production of NTFPs alone, while around half of the people use the forest to generate cash income. In South West, Kaffa zone, wild coffee is the major source of forest income (Melaku *et al*., 2014); in the dry, Afromontane forests in Dendi district, Oromia National Regional State (Mamo *et al*., 2007) and the Bale Highlands (Tesfaye *et al*., 2010), fuel wood is a major contributor to forest income.

Forests contribute more to climate relevant cycles and biodiversity related processes. As stated by Dail (1997), the major services provided by forests includes: Regulation of water regimes, modulating climate, maintenance of soil quality, carbon sequestration, maintenance of biodiversity in themselves and being a habitat for other species, biological control, cultural, aesthetic and desirable feature of a building services.

Forests provide a wide range of products and services catering to a variety of man's socioeconomic needs. The economic values of the forest are the basis of a variety of industries including timber, processed wood and paper, rubber, and fruits. They also contain products that are necessary for rural communities including fuel, construction materials and medicines (FAO, 2005). The rural Ethiopian households entirely depend on biomass fuel to meet their energy requirements for cooking, heating and lighting. Biomass based fuel accounts for 85% and 95% of the total energy and household consumptions respectively. In the share of different biomass based fuels in the total domestic energy, fuel wood and tree residues take 70%, Animal dung 8%, agricultural residues 7% and the rest comes from other sources (EARO, 2000).

Besides its environmental values due to the forest-like setting, a shaded coffee agroforests ecosystem has significant socioeconomic benefits. Planters derive income not only from coffee but also from shade trees and shrubs growing in the coffee plantation. It provides firewood, construction wood, timber, fruit, medicine and shade. The system may also have socio-cultural values that human beings attach to the sites and species, as part of sentiment, culture, aesthetics, history or religion. This is especially true for rural and forest-based communities.

In Peru and Guatemala, the consumption and sale of all non-coffee products of smallholder coffee farms account for 20 to 33% of the total value realized from the agroforests ecosystem. Firewood and fruits account for the bulk of the uses and exchange values coming from the holdings. Fuel wood weighs 60% and 35% of the total value generated by the shade component in Guatemala and Peru, respectively. Coffee also accounts for a large proportion of the total farm income in both countries (Rice 2008). Analysis of the small-scale and cooperative coffee farms' agro biodiversity contribution to livelihoods in Nicaragua and El Salvador showed similar results. Most households obtained 50 to 100% of their annual income from coffee, and 50% of their firewood from coffee farms (Méndez *et al*., 2010). A study in Jimma zone, SW Ethiopia reported a positive relationship between household food security and tree-based land-use systems. The household's income from coffee farm ranges from 200 to 16,000 Ethiopian birr (15 to 1200 USD based on 2010 exchange rate) per annum with an annual average of 2,451 birr (184 USD) (Kebebew and Urgessa 2011).

In addition, the presence of shade trees can control pests, increase yields up to 50%, and improve the size, quality and taste of coffee beans, the optimal levels of shade for doing so varying with climates, elevations and soils (Donald 2004). In Chiapas, Mexico, a complex agroforests ecosystem of rustic coffee, composed of five strata, was correlated negatively with coffee leaf rust (*Hemileia vastatrix* Berk & Br.) and weed covers (Soto-Pinto *et al*. 2002). It also plays a role in beekeeping. For example, coffee and some shade tree species, such as *Acacia sp*., *Albizia sp.*, *Croton macrostachyus*, *Cordia africana*, *Schefflera abyssinica* and some others are among the most important honeybee flora in Ethiopia (Ficht and Adi 1994).

3. MATERIALS AND METHODS

3.1. Description of Study Area

3.1.1. Location

The study was conducted in Mana Districts of Jimma Zone, Oromia National Regional State Southwest Ethiopia. It is found along Jimma-Agaro main road at 20 km from Jimma town. Mana District has an area of 47,891ha and two urban centers such as Yebu and Beleda towns. Manna is bordered on the south by Seka Chekorsa, on the west by Gomma, on the north by Limmu Kosa, and on the east by Kersa. The administrative center of this District is Yebu town (Mana District of Agriculture office MDAO, 2019).

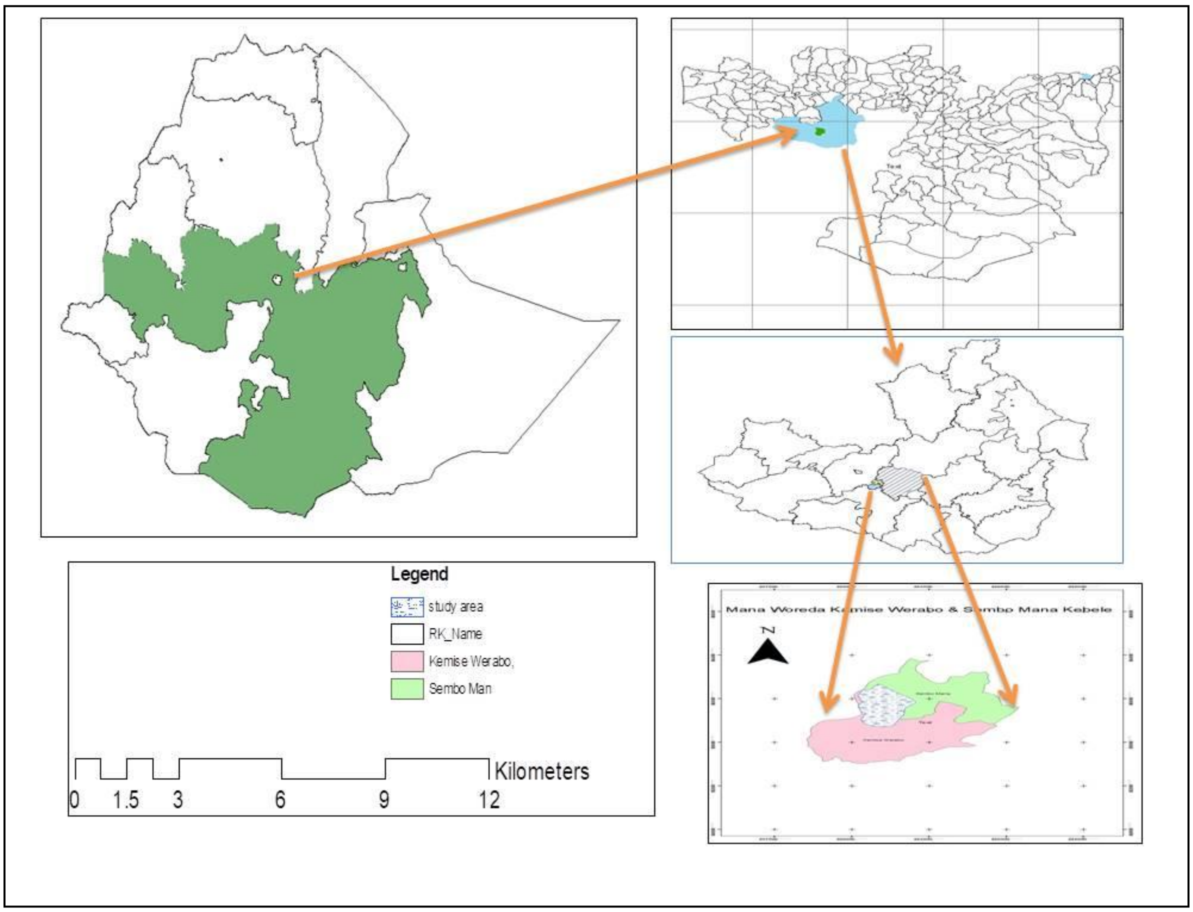


Figure 1: Map of study area

3.1.2. Topography and drainage

The landscape of the District was characterized includes mountains, high forests and plain divided by valleys. The area is characterized by a rough topography, dominated by gentle slopes and a localized steep slopes ranging from 5 to 50%. Several small streams cross the area. The altitude ranges between 1,400 m to 2,610 m above sea level (MDAO, 2019).

3.1.3. Climate and agro climatic zones

The rainfall and temperature data are collected from Mana District Agriculture Office (MDAO, 2019). The mean annual temperature is about 18.85 0C and the mean minimum and maximum temperatures are 13 0C and 24.7 ^{0}C respectively. The mean annual rainfall of the study area is 1467 mm with maximum rainfall between the months of June and September. The District is classified into Dega (12%), Woinadega (63%) and Kola (25%) agro climatic zones (MDAO, 2019).

3.1.4. Demographics

According to (MDAO, 2019), the total population of this District of 196,503 of whom 100,065 (50.9%) were males and 96,438 (49.1%) were females. Of this population, 7,860 (4%) were urban dwellers whereas majority of the inhabitants 188643 (96%) were rural dwellers. The District has an estimated population density of 334.3 people per square kilometer, which is greater than the Jimma Zone average of 150.6 people per square kilometer.

3.1.5. Land use

The proportion of coffee farm, arable and forest lands in Mana District is 55.05%, 31% and 2% respectively .The remaining land area is serves for other purpose (Table 1).

Table 1: Land use pattern of Mana District

No	Land use type	Area in hectare	%
1	Potential arable land	14844	31
2	Grazing land	1067	2.22
3	Forest	945	2
4	Coffee farm	26367	55.05
5	Uncultivable land	272	0.56
6	Construction	2920	6.09
7	Others	1476	3.08
	Total	47891	100

Source: MDAO (2019).

Coffee agroforestry resembles traditional coffee management systems in Southwest Ethiopia, farmers select certain species of trees as coffee shade tree and remove others which they believe having an adverse impact on the coffee shrub growth and productivity (Muleta *et al*., 2011). Even though understanding of the traditional coffee management techniques is however, essential for promoting sustainable coffee agroforestry systems based on the existing local knowledge or for eventually recommending sustainable alternatives.

In Mana District a total of 945 ha area is covered by natural forest from these Bamba natural forest is covering an area of about 300 ha. The forest is located between Kemise Worabo and Sembo Mana Kebele, in Mana District. The topography of the forest is complex, consisting of undulating hills of 1871m to 2120 m above sea level, with steep mountainous terrain in certain locations and intersected by wild rivers. It is centers of high biodiversity of flora and fauna species. This forest is regulated micro-climates and has potential for carbon sequestration, also is important for timber and non-timber forest products. However, this forest is threatened by unsustainable human activities. The most common human activities generate degradation in forests include, clearing for new farmland, illegal timber harvesting and collection of building poles, cutting trees for medicine, collecting fuel wood, livestock grazing and conversion to coffee agroforestry. Property regime of this forest is government; directly authorization of the forest is Mana District Environment, Forest and Climate Change Authority (MDAO, 2019).

3.1.6. Livelihood activities and income

In Mana District, the economic base of the people is directly linked to agriculture, mainly coffee farms followed by production of food crops and rearing of livestock. There are also individuals who rely on both coffee harvesting and farming activities as their major economic activity. These people plant coffee seedlings in their homestead and farm land in addition to cereal crop production system, which serves them as cash crops. Local people are also dependent upon forest and forest products directly or indirectly. They earn their income from coffee beans gathered from coffee farm. Moreover, they hang traditional beehives on the trees and obtain honey products from natural forest. The cereal crops produced in the area include maize, wheat, barley and *teff* and livestock are cattle, sheep, goats, horses and poultry as well as vegetables, honey, milk and chat.

3.1.7. Vegetation

The vegetation type of the study area is broad-leaved and moist montane forest with important species in the forest including *Olea capensis, Schefflera abyssinica, Prunus africana*, *Albizia gummifera, Syzygium guineense, Bersama abyssinica, Pouteria adolfi–friedericii, Apodytes dimidiata, Celtis africana, Croton macrostachyus* and *Ekebergia capensis* (Firiis, 1992).

3.2. Methods

3.2.1. Study site selection

The study area was purposively selected due to the presence of coffee agroforestry and natural forest. Bamba natural forest is surrounding by eight villages and from out of these eight villages, six villages were selected purposively based on bordering within three kilo meter radius from the natural forest. From those village, three villages were selected namely Bamba, Hariro and Yebo are coffee agroforestry users whereas; Werabo, Irebo and Quny are natural forest users.

3.2.2. Vegetation data collection

Coffee agroforestry vegetation data were collected at the center of the coffee farms. We adopted a sampling methodology following Lopez-Gomez *et al*. (2008) and Ambinakudige and Sathish (2009).Accordingly,30 plots of 20m x 20m were selected at the center of the coffee farms based on observation (one plot per household farm). We identified and counted woody species and measured the diameter at breast height (DBH) for trees/shrubs with (≥ 2 m in height, DBH ≥ 10 cm). Hypsometer and diameter tape were used to measure the height and DBH respectively. In each plot, all naturally regenerated woody species were identified. Seedlings (≤ 50 cm in height, < 10 cm DBH) and saplings (> 50cm-2m in height, < 10 cm DBH) were counted in the plots of 5m x 5m and 10 m x 10 m respectively (Kelbessa and Soromessa, 2008). Local name (Afan Oromo) of woody species was identified with the help of local communities in the field. Plant identification were following the nomenclature of plant species published on the Flora of Ethiopia and Eritrea (Edwards *et al*., 2000; Hedberg *et al*., 2006) and Useful Trees and Shrubs for Ethiopia (Bekele, 2007).

Natural forest vegetation data were collected along the transect line, 30 plots of 20m x 20m were selected based on systematic sampling following Kent and Coker (1992) and Muller-Dombois and Ellenberg (1974) was used in this study. The distance between each plots using about 100 m and the distance between each transect lines using about 100 m. Total of six transects were laid down. In each transects line five plots were established. At each natural forest plots, we collected the same data and used the same sampling design as used in coffee agroforests. The starting point of the first transect line was located randomly. To avoid edges effects all sample plots were established at least 50 m from forest the edges or roads inside the forest (Senbeta and Teketay, 2001).

3.2.3. Questionnaire survey

Forest products utilization information was collected through household interview from coffee agroforestry users and natural forest users household respectively. Structured and semi structured questionnaire was prepared to collect the information. The survey question about the respondent general information, forest products utilization from natural forest was the same both coffee agroforestry users and natural forest users household respondents. For coffee agroforestry users household respondent should be asked coffee agroforestry forest products utilization and for natural forest user household respondents not asked coffee agroforestry related question the reason why they are non-coffee growers. For this purpose, questionnaire was translated to the local language (Afan Oromo) which the respondents can listen.

The secondary data source was gathered form Mana Districts Administration Office, Agricultural Office and Kebele Administration Offices.

Household data was collected in Sembo Mana (coffee agroforestry users) and Kemise Werabo Kebele (natural forest users) respectively. The selection of the household heads was undertaken through systematic random sampling technique involving the following steps: First, Villages were categorized coffee agroforestry users and natural forest users. Then, households were selected from lists of household names. Accordingly, to take the sample 30 (coffee agroforestry users) and 30 (natural forest users) household head respondents out of total sample size. A total of 60 households heads were sample size for this study and were determined using the formula following (Kultar, 2007) and decided proportional to the total village population size for this study. For systematic random sampling of respondents the sample interval for picking each respondent the following formula was use.

$$\mathbf{K = \frac{N}{n}}$$

Where n is sample size, N is number of households and k is the pass over interval between sampled farmers. Each sample was taken at the pass over interval and of the 1st was drawn using lottery method.

Table 2: Sample size determination of households

Name of Kebele	Name of village	HH	No. of total HHs	Sample size
Kemise Werabo	Werabo	NF users	79	8
	Irebo		77	8
	Quny		148	14
Sembo Mana	Bamba	CAF users	153	14
	Hariro		82	9
	Yabo		78	7
Total HH			617	60

3.3. Vegetation Data Analysis

Data from all plots was analyzed for vegetative structure (density, basal area and diameter), diversity and composition of woody species. It is tested by independent t-test using Microsoft Excel 2007 and the Statistical Package for Social Sciences (SPSS) version 20.Woody species diversity index, Sorensen's similarity index and Important Value Index were used to analyze. The indexes were calculated using the formula following Magurran (2004).

3.3.1. Woody species diversity indices

Woody species diversity was analyzed using Shannon diversity index (H') and Shannon equitability/evenness index (*E*). These diversity indices provided important information about rarity and commonness of species in a community.

Shannon diversity index (H')

Shannon diversity index was used to characterize species diversity in a community. The Shannon diversity index of species was calculated by the following equation.

$$H' = -\sum_{i=1}^{S} pi\,(ln\,pi)$$

$$pi = n_i/N$$

Where S is the total number of species in the sample, *Pi is* the proportion of individuals in the i^{th} species, n_i is the number of individuals in the i^{th} species and *N* is the total number of individuals in the sample. The value of H' is usually found to fall between 1.5 and 3.5 and only rarely surpasses 4.5. The higher the value of H′, the higher the diversity of the species is (Magurran, 2004).

Shannon evenness (E): Evenness was calculated to compare the observed distribution with the maximum possible even distribution of the number of species in the studied forest (Pielou, 1975) or it is the distribution of individuals among the species in a studied forest. Evenness is maximums when all the species have same or nearly equal number of individuals. Evenness (Shannon equitability) index was calculated as described by Kent and Coker (1992) to estimate the homogeneous distribution of species:

$$E = H'/H'max = H'/lnS$$

The value of Shannon species evenness Index is between zero and one, with one representing a situation in which all species are equally abundant, and lower Shannon species evenness Index indicates higher dominance. As with H', this evenness measure assumes that all species in the community are accounted for in the sample (Magurran 1988). Shannon evenness (*E*) is the descriptor of vegetation (e.g. forest) as whole, and the percentage dominance singles out the most abundant species within each vegetation category (Gole 2003).

3.3.2. Sorensen's similarity index

Sorensen's similarity index (Ss) was calculated to indicate that the degree of similarity in composition of woody species between coffee agroforests and natural forest. It is the common similarity measurement index, which ranges from zero (no species in common) to one (identical set of species). It is calculated with the following formula (Magurran 1988).

$$\mathrm{Ss} = \frac{2C}{A + B}$$

Where, Ss = Sorensen's similarity index
A = number of species in sample one
B = number of species in sample two
C = number of species common to both sample.

3.3.3. Important value index (IVI)

The IVI is useful to compare ecological significance or dominance of woody species in the coffee agroforests and natural forest, which was calculated from the sum of relative dominance, relative frequency, and relative abundance (Kent and Coker, 1992).

IVI= Relative Dominance + Relative Density + Relative Frequency

Basal area

Basal area is the cross-sectional area of woody stems at breast height. It is measured through diameter, usually at breast height that is 1.3 m above ground level. It measures the relative dominance (the degree of coverage of a species as an expression of the space it occupies) of a species in a forest (Mueller-Dombois and Ellenberg, 1974). It is calculated as: BA = π d2/4

Where, = basal area (m2), DBH= diameter at breast height (cm); π = 3.14; d is diameter at breast height.

Diameter

Diameter at breast height data measurement was done using diameter tape and data by following Yasin *et al*., (2018),woody species were categorized into 8 diameter classes: 1= 10-20cm, 2= 20-30cm, 3= 30-40cm, 4= 40.50cm, 5= 50-60cm, 6= 60- 70cm, 7= 70-80cm and 8= >80cm.

Dominance

It refers to the degree of coverage of a species as an expression of the space it occupied in a given area. Usually, dominance is expressed in terms of basal area of the species (Kent and Coker, 1992). Two set of dominance were calculated in this case: dominance (the sum of basal areas of the individuals in m2/ha), and relative dominance, which is the percentage of the total basal area of a given species out of the total measured stem basal areas of all species.

Dominance = Total basal area/ Area sampled

Relative Dominance (RDO) = total basal area of all individuals of a species/total basal area of all species X 100

Frequency

Frequency is defined as the probability or chance of finding a species in a given sample area or quadrate (Moreno-Casasola *et al.,* 2011). Thus, it shows the presence or absence of a given species within each sample plot. Frequency was computed for each woody species encountered within the study plots:

Frequency of species = number of plots in which that species occurs/total number of plots X 100

Relative Frequency (RF) = Frequency of species A/Total sum of frequencies of all species X 100

Abundance

Abundance values were calculated in this study. These were (i) average abundance per plots, calculated as the sum of the number of stems of a species from all divided by the total number plot, (ii) Relative abundance, calculated as the percentage of the abundance of each species divided by the total stem number of all species (Magurran, 2004).

Relative abundance = Number of individuals of species/total number of individuals X 100

Density

The density of woody species was calculated by summing up all stems across all sample plots and converting into hectare basis (Mueller-Dombois and Ellenberg, 1974). It is calculated by following formula:

Density = Total number of individuals/ sample area in (ha)

3.3.4. Community structure

Population structure was drawn based on diameter distribution and regeneration. The regeneration status of the woody species density was analyzed based on seedlings, saplings and mature trees (Dibaba *et al*., 2014) and in the following manners:

1. Seedling > sapling > tree/shrub state, pattern represents good regeneration
2. Seedling outnumbers sapling and tree/shrub state but sapling less than tree/shrub state pattern fair regeneration
3. Seedling < sapling < tree/shrub state, this pattern shows poor recruitment and hampered regeneration
4. With no individual in seedling and sapling stages but relatively many individuals in tree/shrub stage pattern shows no regeneration and hampered regeneration

3.4. Household Data Analysis

In addition to the vegetation data analyzed, household questionnaire surveys were coded, computerized and analyzed using Microsoft Excel 2007 and the Statistical Package for Social Sciences (SPSS) version 20. The forest products utilization data were analyzed using descriptive statistics to describe the household characteristics of the respondents, forest resource utilization differences of respondent levels from coffee agroforestry and natural forest.

4. RESULTS AND DISCUSSION

4.1. Woody Species Composition and Diversity

4.1.1. Woody species diversity

A total of 33 woody species belonging to 24 families were identified and recorded in the study area, of which 25 species belongs to 20 families in coffee agroforests and 30 species belonging to 23 families in natural forest (Table 3). The most dominated families in natural forest were Araliaceae, Boraginaceae, Euphorbiaceae, Fabaceae, Flacourtiaceae, Melianthaceae, Moraceae, Myrsinaceae, Oleaceae and Pittosporaceaeall contributing 8.33% of the species recorded. Correspondingly, for coffee agroforests Fabaceae family was the most diverse family having 15% of the species whereas in natural forest 8.33 % of the species (Table 3). The family of Fabaceae represented the majority of woody species in coffee agroforests. This study is support by Bajigo and Tadesse (2015) who reported that the family Fabaceae as the dominant family of the woody species recorded in the Wolayitta zone. Fabaceae families were dominant in the southeastern rift valley escarpment of Ethiopia (Negash *et al*., 2012).

Woody species density per hectare in the coffee agroforests and in the natural forests was 190 and 243 respectively. Woody density per hectare in the coffee agroforests was lower than in the natural forests (Table 3). The mean woody density in the coffee agroforests in the current study was much higher than the one reported by Tadesse *et al*. (2001) which was 60 trees per hectare 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) in Mexico which were 464 and 371.4 per hectare, 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 woody species density in the coffee farms was 190 individuals per hectare from the current study. The possible reasons lower the number of woody species diversity due to farmer's species selection for shade purpose, selective woody thinning and intensive human interference or management of shade woody species.

Table 3: Recorded woody species with their family and density per hectare in coffee agroforestry and natural forest the case of Mana District**,** southwest Ethiopia

S/N	**Scientific name**	**Family**	**NF**		**CAF**	
			Observed	per ha	Observed	per ha
1	*Acacia abyssinica*	Fabaceae	-	-	12	10
2	*Albizia gummifera*	Fabaceae	-	-	29	24
3	*Apodytes dimidiate*	Icacinaceae	4	3	5	4
4	*Allophylus abyssinicus*	Sapindaceae	9	8	5	4
5	*Bersama abyssinica*	Melianthaceae	5	4	1	1
6	*Celtis africana*	Ulmaceae	5	4	2	2
7	*Cordia africana*	Boraginaceae	7	6	26	21
8	*Croton macrostachyus*	Euphorbiaceae	32	27	36	29
9	*Brucea antidysenterica*	Simaroubiaceae	4	3	5	4
10	*Diospyros abyssinica*	Ebenaceae	4	3	-	-
11	*Ekebergia capensis*	Meliaceae	8	7	4	3
12	*Erythrina brucei*	Fabaceae	5	4	-	-
13	*Euphorbia abyssinica*	Euphorbiaceae	5	4	-	-
14	*Ficus sycomorus*	Moraceae	4	3	2	2
15	*Ficus vasta*	Moraceae	2	2	1	1
16	*Flacourtia indica*	Flacourtiaceae	7	6	2	2
17	*Galiniera saxifrage*	Rubiaceae	15	12	7	6
18	*Grevillea robusta*	Proteaceae	-	-	4	3
19	*Ilex mitis Radlk.*	Aquifoliaceae	2	2	-	-
20	*Macaranga capensis*	Euphorbiaceae	4	3	-	-
21	*Maesa lanceolata*	Myrsinaceae	6	5	6	5
22	*Millettia ferruginea*	Fabaceae	21	18	32	27
23	*Olea capensis*	Oleaceae	15	13	4	3
24	*Olea welwitschii*	Oleaceae	11	9	6	5
25	*Pittosporum viridiflorum*	Pittosporaceae	5	4	2	2
26	*Podocarpus falcatus*	Podocarpaceae	8	7	-	-
27	*Polyscias fulva*	Araliaceae	19	16	11	9
28	*Pouteria adolfi-friederici*	Sapotaceae	6	5	-	-
29	*Prunus africana*	Rosaceae	11	9	5	4
30	*Schefflera abyssinica*	Araliaceae	14	12	5	4
31	*Syzygium guineense*	Myrtaceae	31	26	15	13
32	*Teclea nobilis*	Rutaceae	13	11	-	-
33	*Vernonia amygdalina*	Asteraceae	8	7	2	2
			290	243	229	190

Sorensen's similarity index showed that the coffee agroforests and natural forest share high woody species (80%). Out of a total of 33 woody species, 22 (66.6%) were common to both coffee agroforests and natural forest, while 3 (9%) and8 (22.24%) woody species were found only in coffee agroforests and natural forest, respectively. The observed similarity in woody species composition between coffee agroforestry and natural forest revealed that the woody species in the coffee agroforests are established from natural forest by intensifying management on woody species and they had the same species combination and remnants of the past forest. The study is supported by Negawo and Beyene (2016), Sorenson similarity index indicates that coffee agroforestry and natural forest were similar by about 56 % of their species composition in Eastern Uganda. This finding supported by Yasin *et al*., (2018), Sorenson similarity index indicates that coffee agroforestry and natural forest were similar by about 47.19% of their species composition the case of Belete forest, Southwest Ethiopia.

Although the result shows no statistically difference ($p > 0.05$) between coffee agroforestry and natural forest. Many previous study shows by Likassa and Gure (2016), 49 different woody species were recorded in natural forest whereas 36 woody species were recorded in the coffee agroforestry in small holder coffee farms of western Oromia, Ethiopia. On the other hand, Tadesse *et al.,* (2014) recorded 44 woody species in natural forest and 27 woody species in semi-forest of coffee in south west of Ethiopia. Shannon's diversity index of woody species in coffee agroforests (H' = 2.32) and natural forest (H'= 3.15). The higher H value in natural forest indicates higher diversity. This difference may be explained in terms of the management practices in the coffee agroforests and natural forest. Coffee farms were generally characterized by selective retention of some amount of over story as shade woody 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.

Coffee agroforests is generally expected to have lower number of woody species than natural forest since coffee farms need continuous management that eliminates seedling, sapling and shrubs to create free space for coffee shrubs so as to reduce competition. According to, 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 woody species diversity (Ambinakudige and Sathish, 2009).

Table 4: Diversity of woody species in coffee agroforests and natural forest

Diversity	Coffee agroforests	Natural forest	P-value
Richness	25	30	0.193
Shannon index	2.32	3.15	-
Evenness	0.72	0.92	-

Shannon's evenness for coffee agroforests and natural forest were 0.72 and 0.92 respectively (Table 4).The evenness measure assumes a value between 0 and 1 with 1 being complete evenness (Magurran 2004). This indicates that there is not much difference in the evenness among the coffee agroforests and natural forest. This study supported by Yasin *et al*., (2018) who reported that Shannon evenness of woody species was no significant difference observed between natural forest and coffee agroforestry.

4.1.2. Importance value index

The IVI is an aggregate index that summarizes the density, dominance and frequency of a species. IVI of all woody species in the coffee agroforests and natural forest were listed in (Appendix 5 and 6). Accordingly, the ten leading dominant and ecologically important woody species in coffee agroforests and natural forest were given in descending order in (Table 5). The woody species with the highest IVI were *Albizia gummifera* (38.95%), *Millettia ferruginea* (34.27%) and *Croton macrostachyus* (32.82%) in coffee agroforests. Whereas in natural forest, highest IVI were *Syzygium guineense* (34.41%), *Schefflera abyssinica* (30.89%), and *Croton macrostachyus* (24.54%) followed by other species. Importance value index showed that overall importance of a species and gives an indication of the ecological success of a species in a particular area. Importance Value Index (IVI) is an important parameter that indicates the ecological significance of species in a given ecosystem (Worku *et al*., 2012).

Table 5: Importance value index of woody species in coffee agroforests and natural forest

S/N	Coffee agroforests		Natural forest	
	Botanical name	IVI	Botanical name	IVI
1	*Albizia gummifera*	41.44	*Syzygium guineense*	34.41
2	*Millettia ferruginea*	36.34	*Schefflera abyssinica*	30.89
3	*Croton macrostachyus*	33.49	*Croton macrostachyus*	24.54
4	*Cordia africana*	30.74	*Polyscias fulva*	22.5
5	*Syzygium guineense*	20.34	*Prunus africana*	15.94
6	*Polyscias fulva*	19.74	*Millettia ferruginea*	15.89
7	*Acacia abyssinica*	15.55	*Olea welwitschii*	15.73
8	*Prunus africana*	11.17	*Pouteria adolfi-friederici*	14.86
9	*Schefflera abyssinica*	10.85	*Olea capensis*	10.59
10	*Olea welwitschii*	10.22	*Galiniera saxifraga*	10.28

The high IVI value of woody species is mainly due to their high dominance, which may be due to their demand by the local people for different purposes. Species with high IVI values regarded as more important than those with low IVI values (Zegeye *et al*., 2011). Therefore, the IVI values can be used to species conservation and species with high IVI value need less conservation efforts, whereas those having low IVI value need high conservation effort. Thus, IVI is the most reasonable aspect in the vegetation study. Moreover, species with the greatest importance value are the most dominant of particular vegetation in the forest (Simon and Girma, 2004).

4.1.3. Community structure

Distribution of all individuals in different DBH size classes in the coffee agroforests and natural forest showed more or less inverted J-shape, there were greater numbers of individuals in the lower diameter size class. Coffee agroforests, 49.47 % and natural forest, 55.20% of individuals were concentrated in the first lower diameter size class. Only1.57% in coffee agroforests and 1.64% in natural forest were found in the higher diameter size class (> 90 cm). Generally, diameter class distribution was an inverted J- shape, which showed that the species was more in the lower diameter classes and decreased gradually towards the higher classes.

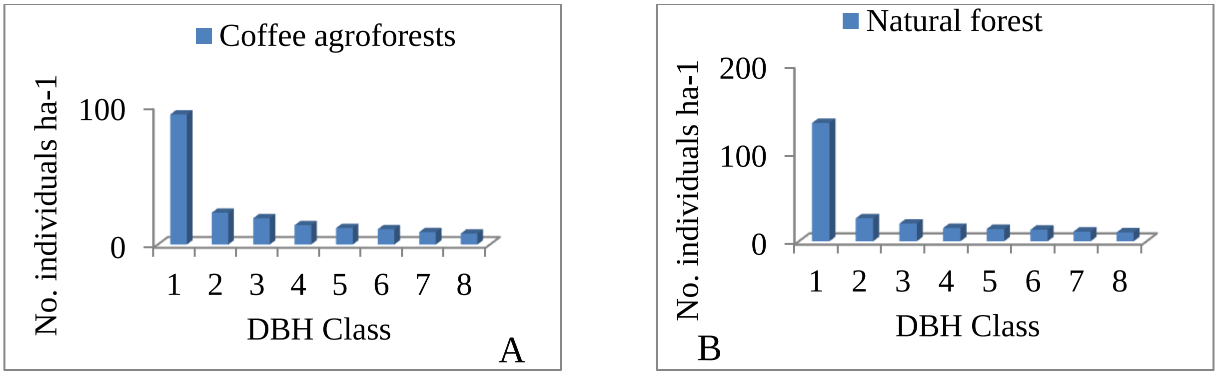


Figure 2: Diameter class distributions of woody species in coffee agroforests (A) and natural forest (B).

Note:DBH class:1 = 10-20 cm; 2 = 20.1-30 cm; 3 = 30.1-40 cm; 4 = 40.1-50 cm and 5 = 50.1-60 cm; 6=60.1-70 cm; 7=70.1-80 cm and 8 = >80 cm.

Some of woody species density distribution of diameter classes of tree/shrubs species resulted in different patterns in both coffee agroforests and natural forest (Figure 3). The highest DBH of trees/shrubs in coffee agroforests > 90 cm was contributed by *schefflera abyssinica* and in natural forest highest DBH >100 cm were recorded by *Pouteria adolfi-friederici* species. The overall structure of the coffee agroforestry and natural forest can help understand the status of regeneration. Reverse J-shaped distributions indicated more or less a healthy or stable regeneration (Worku *et al*., 2012). This means high numbers of individuals in the lower diameter classes but decreases towards the higher classes. Overall distribution of diameter classes of individuals of all tree/shrubs species encountered indicates a relatively high proportion of individuals in lowest diameter class, which form potential source of recruitment to successively increasing diameter classes that ensures sustained future regeneration of the forest if properly managed. However, the number of individuals in the next higher diameter classes declined considerably suggesting that there is interference that can be attributed to unsustainable exploitation of tree species in forest by the local people both for domestic consumption and for generating income.

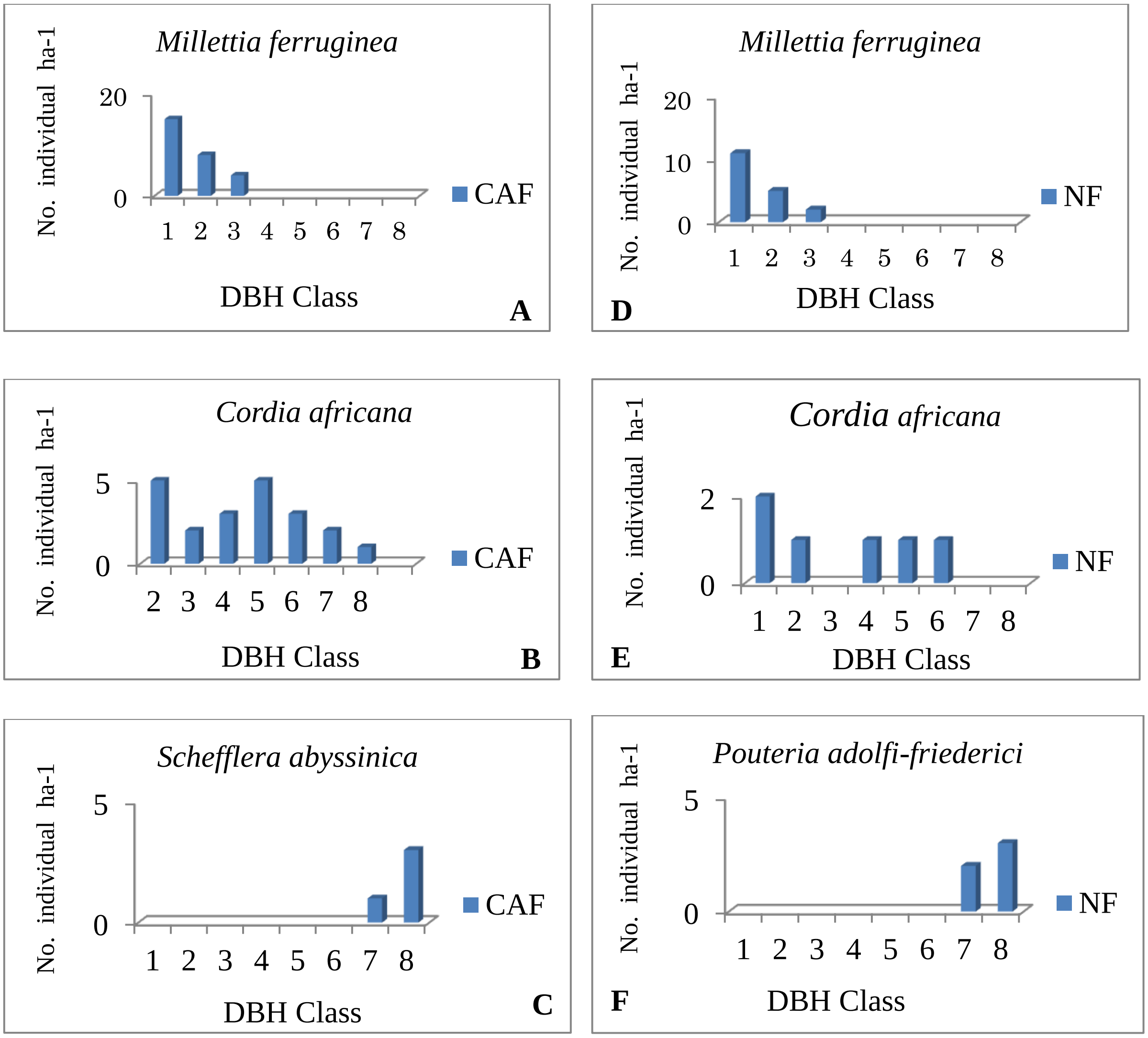


Figure 3:DBH class of some /selected woody species in coffee agroforests (A, B and C) and natural forest (D, E and F).

Note: DBH class: 1 = 10-20 cm; 2 = 20.1-30 cm; 3 = 30.1-40 cm; 4 = 40.1-50 cm and 5 = 50.1-60 cm; 6=60.1-70 cm; 7=70.1-80 cm and 8 = >80 cm.

4.2. Regeneration Status

The present study showed that the coffee agroforestry had lower density of seedling and sapling than natural forest. The mean density (number of individuals ha-^{1}) of seedlings and sapling of the woody species indicated significant ($P < 0.05$) differences between coffee agroforestry and natural forest (Table 6). This showed that natural forests have higher regeneration status than coffee agroforests. However, the mean density of tree in coffee agroforests and natural forest show no statistically difference (p > 0.05). When the natural forests are converted into coffee agroforests regeneration of woody species decreased. Traditional coffee management system for coffee production is opening up undisturbed forest by clearing undergrowth vegetation competing with coffee and cutting some shade woody to open up canopy. During the coffee management practice, the understory small shrubs and herbaceous layer are frequently cleared to reduce competition on coffee shrubs and enhance coffee production. Therefore, coffee management was reducing regeneration of species to improve the productivity of the coffee in coffee agroforests. This study is supported by Tadesse *et al*. (2014) reported that natural forest fragments have higher regeneration and recruitment than the semi-forest and semi-plantation coffee of the smallholder farmers. This study is also agreed with (Senbeta and Denich, 2006; Hylander *et al*., 2013) who reported that intensive wild coffee management in forest-fragments would reduce density, regeneration of species.

Table 6: Density of seedling, sapling and mature tree/shrubs of coffee agroforests and natural forest

Growth stages	Coffee agroforests	Natural forest	P-value
	Density per hectare	Density per hectare	
Seedling	613	1213	0.021
Sapling	225	364	0.032
Tree	190	243	0.256

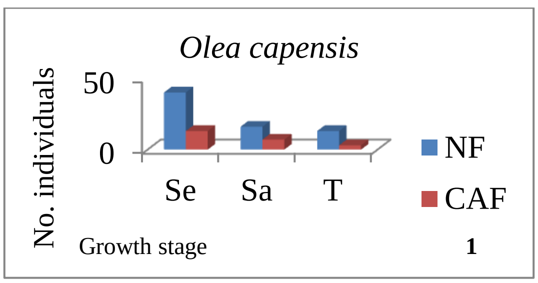
Based on the regeneration status of the woody species occurring in the coffee agroforests and natural forest, some of representative of woody species of seedling, sapling and mature tree/shrubs status were recorded (Figure 4). Accordingly, four patterns were observed for regeneration patterns of the woody species in the coffee agroforests and natural forest (Appendix 7). They are:

1. Seedling > sapling > tree/shrubs state, e.g. *Olea capensis* this pattern represents good regeneration and recruitment. Abundance of seedlings and saplings are indicators of the establishment of young individuals.

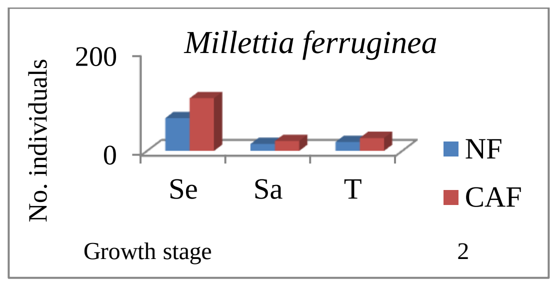
2. Seedling out numbers sapling and tree state but sapling less than tree/shrub state, e.g. *Millettia ferruginea* pattern represents fair regeneration and recruitment of the species.

3. Seedling < sapling <mature tree/shrub state, e.g. *Syzygium guineense* and *Polyscias fulva* pattern shows poor reproduction and hampered regeneration due to the fact that most trees are not producing seeds as a result of their old age or there has been loss of seeds by predators after reproduction.

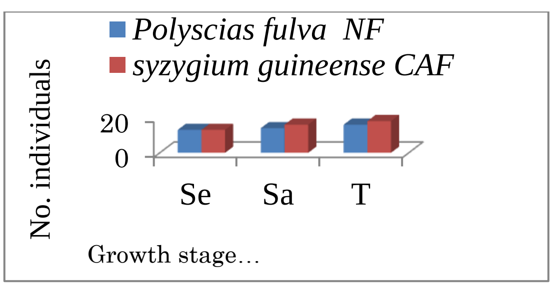
4. No individual in seedling and sapling stages but relatively many individuals in mature tree/shrubs stage e.g. *Prunus africana* this pattern shows poor reproduction and hampered regeneration. In this pattern, some of the mature tree/shrubs lacked seedlings and /or saplings. This suggests that the regeneration from seedling and sapling reduced and these species may aggravate the local extinction of species in the future. Coming to the conservation priorities, the regeneration of woody species categories 3 and categories 4 would be give the first priority for conservation because they are at higher risk of local extinction.



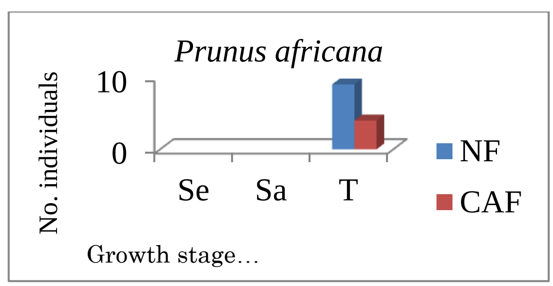
This pattern represents good regeneration



This pattern represents fair regeneration



This pattern shows poor regeneration



This pattern shows no regeneration

Figure 4: Regeneration status of woody species in coffee agroforests and natural forest

Note: Se = Seedling, Sa = Sapling, T = Mature Tree/shrubs

4.3. Forest Resources Utilization

4.3.1. Forest products utilized from coffee agroforestry and natural forest

The survey result showed that various forest products were collected by household respondents for home consumption and the forest products were obtained from coffee agroforests and natural forest.

As indicated in (Figure 5), the major forest products obtained from coffee farm reported by coffee agroforestry user household respondents include firewood, charcoal, construction wood, fodder/grass, medicine, timber and honey. Most of the household respondents 70% collected firewood from coffee agroforests. Another popular product was charcoal 60% followed by construction wood (56%) and fodder/grass (53%). Other products which made important contribution to household forest utilization were medicine, timber and honey each contributed 20%, 26% and 13%, respectively.

In case of the major forest products obtained from natural forest reported by coffee agroforestry user household respondents include firewood, medicine, construction wood, forest coffee and honey. Most of the household respondents 40% collected medicine from natural forest. Another forest product which made significant contribution to household respondent forest utilization firewood, construction wood, forest coffee and honey each contributed 10, 13%, 10% and 6%, respectively.

Coffee agroforests users were found to reduce forest products extraction from natural forest and independency positively. This study supported by Schroth *et al*., (2004), coffee grown under the shade of or in association with native forest trees and sustain rural livelihoods and support high amounts of biodiversity. Shaded coffee production system has received considerable attention from conservation organizations in recent years in which it supports cash income generation from the sale of both timber and non- timber forest products (Gordon *et al*., 2007). Evidence suggests that NTFPs "ensuring food security, providing cash income, livelihood security and diversification" (Shackleton and Gumbo, 2010).

Note: a total result is greater than samples because it is multiple response answer

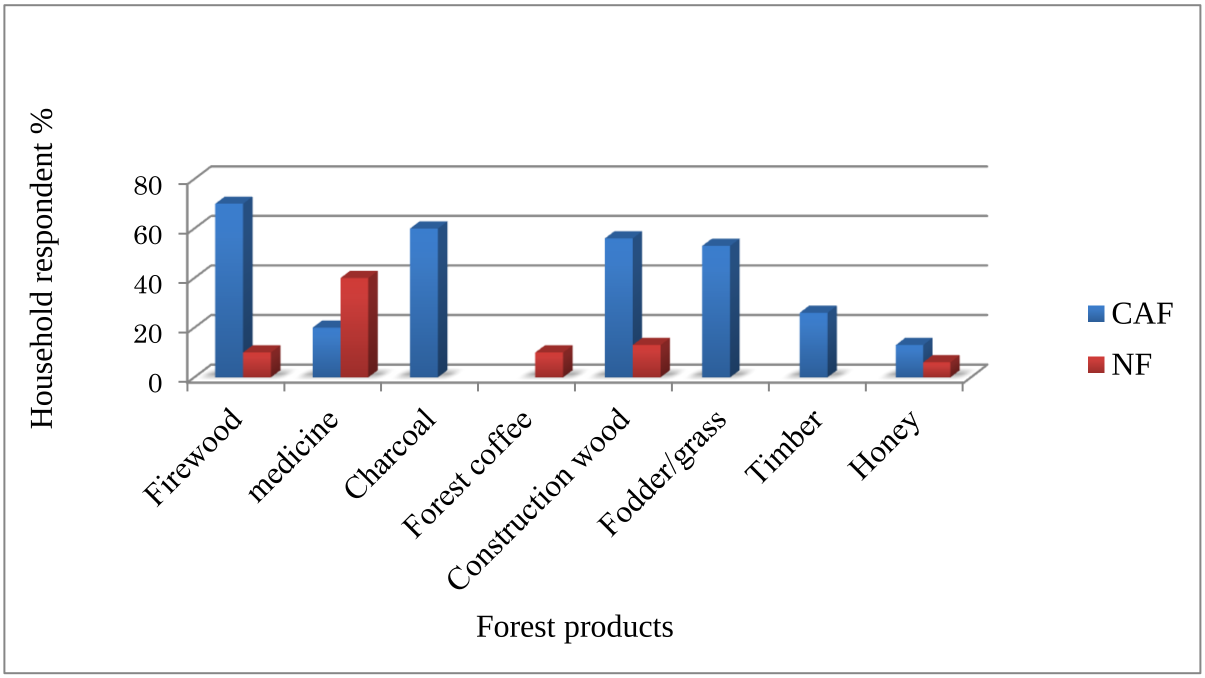


Figure 5: Forest products utilization from coffee agroforestry and natural forest by CAF users

The result indicated that, forest products utilization from natural forest by coffee agroforestry user household respondents differ depending on coffee farm land holding sizes has an effect on forest products extraction.

Table 7. Coffee farm land size of coffee agroforestry user respondents

Land size (ha)	Frequency	Household respondent %
0.25 - 0.5	8	26.6
0.5 - 1.75	22	73.4
Total	30	100.0

The household coffee agroforests land holding size is one of the limiting factors for better management of the existing coffee agroforests and natural forests as well as to minimize pressure on the natural forest.

The survey result indicated that there is variation in coffee farm land holding sizes among the various coffee agroforestry users household. According to total coffee land holding size reports, 73.3% of the coffee agroforestry user household respondent's have 0.5 to 1.75 hectare coffee farm land. Whereas, 26.7% of the coffee agroforestry user household respondents have less than 0.5hectare coffee farm land holders. In this study, larger coffee farm land holder household is significantly decreased the level of dependency on forest product extraction in addition, can get dead branches or wood from their own farms for their fuel wood and lumber needs. The implication was that coffee farm landholding size was influence forest product extraction and dependency negatively. Most households look forward to harvesting forest products from their owned land and a considerable increase in their cash income from coffee agroforestry. Therefore, the household of coffee agroforestry users decrease their dependence of forest products extraction from the natural forests.

4.3.2. Forest product utilized from natural forest

The survey result showed that diverse forest products were collected by households for home consumption and the products were obtained from natural forest. As indicated in (Figure 6), the major forest products obtained from natural forest reported by natural forest user households include firewood, medicine, charcoal, forest coffee, construction wood, fodder/grass, timber and honey. Most of the household respondents 86% collected firewood from natural. Another popular product was medicine 63% and 56% of forest product utilization is households reportedly obtained from charcoal and 53% from forest coffee. Other products which made important contribution to household forest utilization construction wood, fodder/grass, timber and honey each contributed 46%, 46%, 40% and 26%, respectively.

Note: a total result is greater than samples because it is multiple response answer

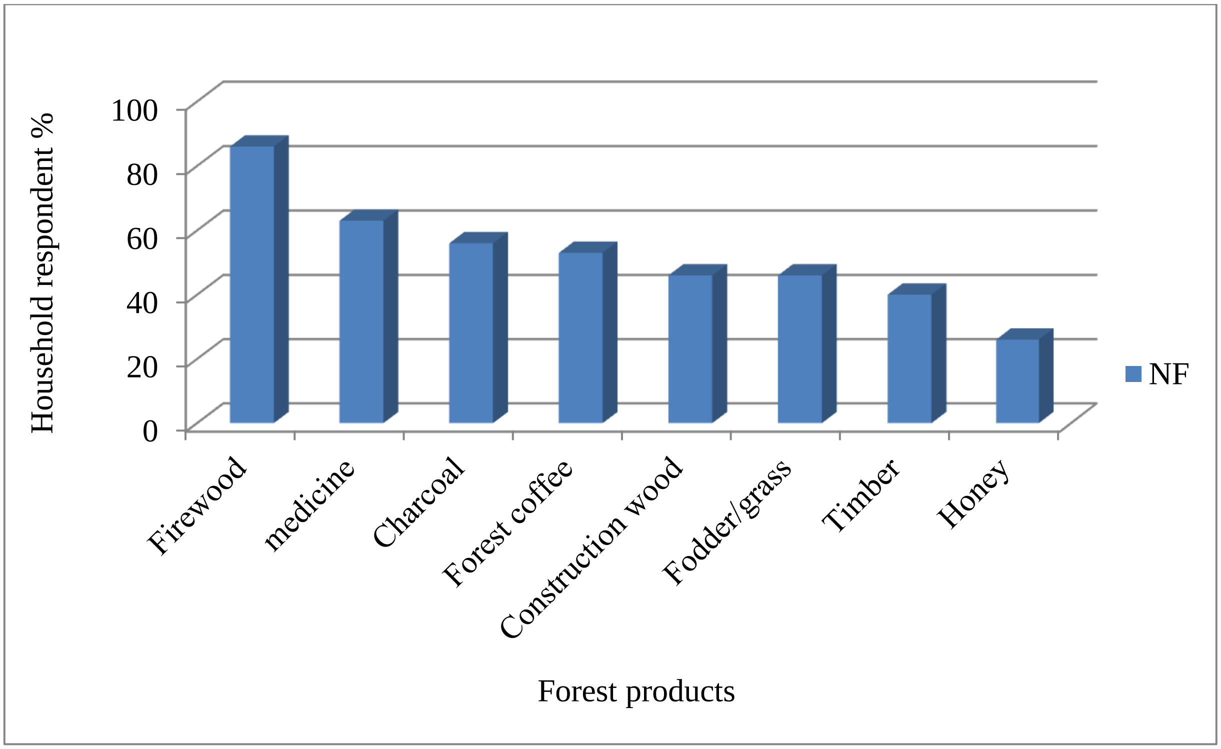


Figure 6: Forest product utilization from natural forest by NF users

This study agree with the findings of Adilo (2007) who reported that major sources of cash income for households, were NTFPs, such as forest coffee, honey and spices. The household respondent of natural forest users increases their dependence of forest products extraction from the natural forest. Hence, adaptation of coffee agroforestry system decreases their dependence of forest products extraction from the natural forests. Natural forest users household respondent do not adaptation of coffee agroforestry system due to environmental condition.

4.3.3. Forest products utilization and access

The livelihood of the study area largely depends on timber and non-timber forest products in coffee agroforests and natural forest.

The result showed that in (Figure 7), 90% of coffee agroforestry user household respondents report that there is restricted access to forest products from coffee farm for community members because of their property whereas, 10% of the household respondents indicated that they have access to collect forest products in coffee agroforestry. They were allowed to collect some of forest products such as fuel wood and medicinal plants after the coffee harvested. Accordingly, coffee agroforestry under the ownership of farmers have existed so far mainly because of the way they have been cultivating coffee with a management for most of the time restricted because clearing of undergrowth before collection of coffee berries.

However, 80% of coffee agroforestry user household respondents stated that there is restricted access to forest products from natural forest because coffee agroforestry user collected different forest products from their own coffee farms whereas, 20% of coffee agroforestry user household respondents revealed that they have access to collection of different forest products as common from the natural forest because lack of enforcement of the rules that protect the forests.

Yet, in the natural forest users, 93.3% of natural forest user household respondents stated that they have access to collection of different forest products as common from the natural forest because lack of enforcement of the rules that protect the forests whereas, 6.6% household respondents revealed that there is restricted access to collection of different forest products restricted in natural forest.

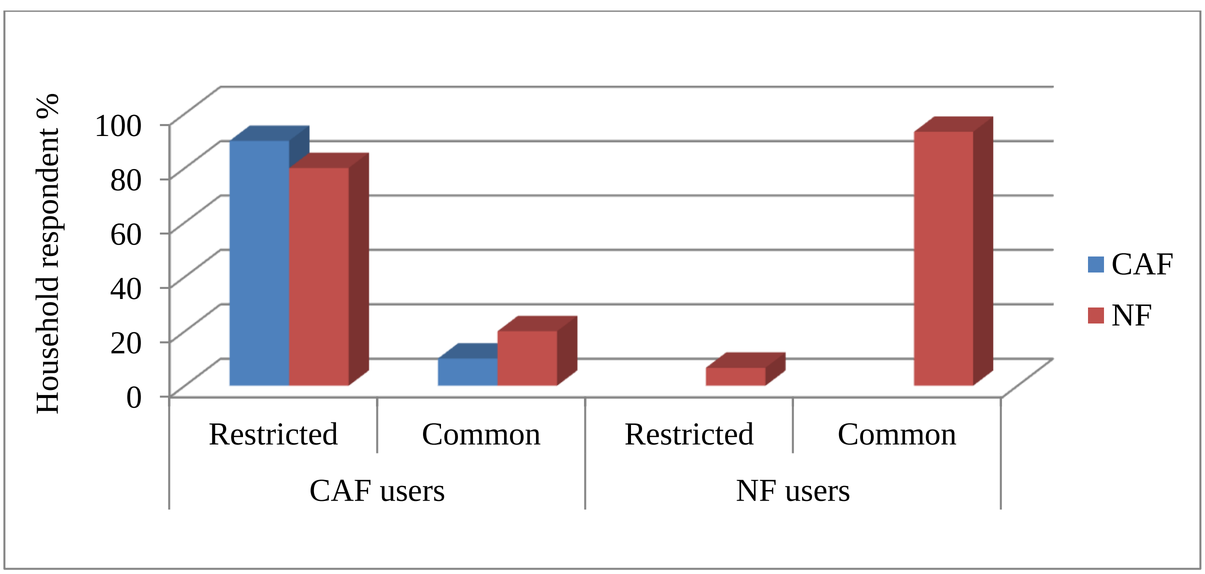


Figure 7: Forest products utilization and access from coffee agroforestry and natural resource by CAF and NF users

Forest products in the natural forest are accessible to any community member because lack of enforcement of the rules that protect the forests. There are government rules that protect forest products utilization access. Most of the government rules that protect natural forests are not known by community members. There is lack of enforcement of rules by traditional leaders and government which could be the leading reasons for high frequency of illegal harvesting of forest products from the natural forest. Generally, most households in the natural forest users depend on accessing forest products for their day-to-day use. Consequently, there are problems of deforestation, degradation, illegal harvesting. Coffee agroforestry contributes to conservation of woody species through retention woody species and reducing pressure on the natural forest, which may be a reflection of conservation of biodiversity and utilization of forest products. Households located within Ethiopia forest farm interface tend to be highly dependent upon forest resources for fuel wood, livestock grazing and building materials (Mamo *et al*., 2007). The result is supported by Dayal (2006), who reported that forest product extraction and the extent of natural resource degradation is often attributed to rapid population growth and open access nature of those resources, especially forests. Recently, however, the uses of forest services have been diminished in southwest Ethiopia due to lack of ownership and local access to the use of forests following land-tenure changes (Tadesse *et al*., 2013).

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Natural forest has a vast ecological and economic importance, but due to human induced factors, there is a persistently high rate of biodiversity loss. There is need of biodiversity conservation. The results of the present study confirm that coffee agroforests and natural forest constitutes larger proportion of tree species, which may be a reflection of conservation of biodiversity.

Coffee agroforests is conserving tree species by doing management practice in maintaining more species as shade of coffee and economically useful species.

A total of 33 woody species belonging to 24 families were identified and recorded in the study area, of which 25 species belongs to 20 families in coffee agroforests and 30 species belonging to 23 families in natural forest.

The woody species with the highest IVI were *Albizia gummifera*, *Millettia ferruginea* and *Croton macrostachyus* in coffee agroforests. While in the natural forest, highest IVI was Syzygium *guineense, Schefflera abyssinica* and *Croton macrostachyus*. These woody species were adapted to the high pressure of disturbance, natural and environmental factors and the effect of local communities. This implied that these adapted woody species were the most ecologically important species. The woody species having low IVI values and poor regeneration status need to be prioritized for conservation.

Distribution of all individuals in different DBH size classes in the coffee agroforests and natural forest showed more or less inverted J-shape, there were greater numbers of individuals in the lower diameter size class.

The result of regeneration status showed that the coffee agroforestry had lower density of seedling and sapling than natural forest. The mean density (number of individuals ha^{-1}) of seedlings and sapling of the woody species indicated significant ($P < 0.05$) differences between coffee agroforestry and natural forest. This showed that natural forests have higher regeneration status than coffee agroforests. However, the mean density of woody in coffee agroforests and natural forest show no statistically difference ($p > 0.05$). When the natural forests are converted into coffee agroforests regeneration of woody species decreased.

The level of forest resource utilization results show that natural forest user respondents are more forest resource utilizing related incomes and are illegally involved in the collection and extraction of forest products from natural forest. Whereas coffee agroforestry users had creates an opportunity to obtain forest resource utilizing related incomes from their own coffee farm. The active involvement of coffee agroforestry users shows that they are aware of the value of on-farm tree diversity for the sustenance of their livelihood. This implies that coffee agroforests indirectly contribute to the conservation of biodiversity through reducing pressure that would be exerted on natural forests, so coffee agroforests serve as a buffer zone in natural forest conservation.

5.2. Recommendations

The results of the study have implications in redefining research and extension strategies towards a conservation and livelihood approach.

- Conservation practitioners and policy makers seeking to promote coffee agroforestry as tree species diversity conservation under sound management guidelines that dictates use and conservation forest resources.
- By creating proper linkage with the Office of Agriculture for sustainable intensification path ways to agroforestry, intercropping and crop rotation, it is possible to increase productivity on the available land so that encroachment to the forestland for expansion of farmlands could be minimized.
- Conservation of tree species and forest products utilization must be linked in the arena of conservation approaches
- Further studies would be required on advanced regeneration tree species with no regeneration as it disappears in future

This study was conducted at specific site with limited experience. Therefore, similar study should be conducted in other part of the country to get reliable information on the role of coffee based agroforestry in tree species diversity conservation**.**

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7. APPENDIX

APPENDIX

Appendixes 1: Questioner survey formats

The questionnaires contain two parts. The first part questionnaire was interview households those are coffee agroforestry users and the second part questionnaires was interview households those are natural forest users.

Part one

Questionnaires intended to collect data from coffee agroforestry users

1: Respondent's general information

4. Name of the respondent: ______________ Kebele _________ Village ____________
5. Age ___ Sex ___ education level of respondent_____ Marital status: _________
6. Family size: Male ______Female _____ Total ____
7. Total land holding size (ha): _______________
8. How long have you been living in this area (specify)? __________________
9. Total area of Coffee Agroforestry (ha) ________________
10. How far is the coffee farm and natural forest from your house (in kilometers) _______
11. How far is the natural forest from your house (in kilometers) _______
12. Total annual income _____________

Considering all sources, what is the income of your family? Please mark up to four major sources of income of your household (from 1 to 4, 1 when is the most important and 4 least important):

No		Mark major sources of income	Per year (birr)
1	Coffee product		
2	Forest coffee product		
3	Farming land		
4	Livestock selling		
5	Forest products		
6	Second job		
7	Other (specify)__________________		
Total annual income			

2: Forest resource utilization

2.1. What forest resource do you use from coffee agroforestry and natural forest?

13. Please specify up to five uses in priorities from 1 to 5, with 1 being the most important in your household?

No.	**Use type**	CAF	NF
1	Firewood		
2	Charcoal		
3	Construction wood		
4	Fodder/grass		
5	Medicine		
6	Timber and		
7	Honey		
8	Other use (specify) ___________________________		

3: Forest resource utilization access

2.1. How do you rate access use of coffee agroforestry and natural forest?

Access use	**CAF Users**		**NF Users**
	CAF	NF	NF
Forest resource access uses (Restricted/ Common)			
Ownership feeling (private/ state)			

Part two

Questionnaires intended to collect data from natural forest users.

2. Forest resource utilization

2.1. What forest resource do you use from natural forest?

- Please specify up to five uses in priorities from 1 to 5, with 1 being the most important in your household?

No.	Use type	NF
1	Firewood	
2	Charcoal	
3	Construction wood	
4	Fodder/grass	
5	Medicine	
6	Timber and	
7	Honey	
8	Other use (specify) ______________________________	

3: Forest resource utilization access

2.1. How do you rate access use of natural forest?

Access use	NF
Forest resource access uses (Restricted/ Common	
Ownership feeling (private/ state)	

Appendixes 2: Botanical name of woody species in coffee agroforests

S/N	Botanical name	Family	Vernacular name (Afan Oromo)
1	*Acacia abyssinica Hochst ex Benth.*	Fabaceae	Laftoo
2	*Albizia gummifera (J.F.Gumel.) C.A.Sm*	Fabaceae	Ambebesa
3	*Allophylus abyssinicus (Hochst.) Radlkofer*	Sapindaceae	Se’o
4	*Apodytes dimidiata E.Mey.ex Am.*	Icacinaceae	Wendebyo
5	*Bersama abyssinica Fresen.*	Melianthaceae	Lolchiisaa
6	*Brucea antidysenterica J.F. Mill.*	Simaroubiaceae	Qomenno
7	*Celtis africana Burm.f.*	Ulmaceae	Qahee
8	*Cordia africana Lam.*	Boraginaceae	Waddessaa
9	*Croton macrostachyus Del.*	Euphorbiaceae	Makanisa
10	*Ekebergia capensis Sparm.*	Meliaceae	Sombo
11	*Ficus sycomorus L*	Moraceae	Harbu
12	*Ficus vasta Forssk.*	Moraceae	Qilxuu
13	*Flacourtia indica (Brm.f.) Merr*	Flacourtiaceae	Akuukkuu
14	*Galiniera saxifraga (Hochst.) Bridson*	Rubiaceae	Simararu
15	*Grevillea robusta*	Proteaceae	Grevillea
16	*Maesa lanceolata Forssk.*	Myrsinaceae	Abbayyii
17	*Millettia ferruginea (Hochst.) Bak.*	Fabaceae	Askra
18	*Olea capensis L.*	Oleaceae	Gagama
19	*Olea welwitschii (Knobl.) Gilg & Schellenb*	Oleaceae	Baya
20	*Pittosporum viridiflorum Sims*	Pittosporaceae	Sole
21	*Polyscias fulva (Hiern) Harms*	Araliaceae	Kariyo
22	*Prunus africana (Hook.f.) Kalkm*	Rosaceae	Oomoo
23	*Schefflera abyssinica (Hochst. ex A. Rich.) Harms*	Araliaceae	Botto
24	*Syzygium guineense (Willd.) DC. subsp. afromontanum F. White*	Myrtaceae	Bedessa
25	*Vernonia amygdalina Del.*	Asteraceae	Ebbichaa

Appendixes 3: Botanical name of woody species in natural forest

S/N	Botanical name	Family	Vernacular name (Afan Oromo)
1	*Allophylus abyssinicus (Hochst.) Radlkofer*	Sapindaceae	Se'o
2	*Apodytes dimidiata E.Mey.ex Am.*	Icacinaceae	Wendebyo
3	*Bersama abyssinica Fresen.*	Melianthaceae	Lolchiisaa
4	*Brucea antidysenterica J.F. Mill.*	Simaroubiaceae	Qomenno
5	*Celtis africana Burm.f.*	Ulmaceae	Qahee
6	*Cordia africana Lam.*	Boraginaceae	Waddessaa
7	*Croton macrostachyus Del.*	Euphorbiaceae	Makanisa
8	*Diospyros abyssinica (Hiern.) F.White*	Ebenaceae	Lookoo
9	*Ekebergia capensis Sparm.*	Meliaceae	Sombo
10	*Erythrina brucei Schweinf*	Fabaceae	Wolensu
11	*Euphorbia abyssinica Gmel.*	Euphorbiaceae	Adaamii
12	*Ficus sycomorus L*	Moraceae	Harbu
13	*Ficus vasta Forssk.*	Moraceae	Qilxuu
14	*Flacourtia indica (Brm.f.) Merr*	Flacourtiaceae	Akuukkuu
15	*Galiniera saxifraga (Hochst.) Bridson*	Rubiaceae	Simararu
16	*Ilex mitis Radlk.*	Aquifoliaceae	Miessaa
17	*Macaranga capensis (Baill.) Sim.*	Euphorbiaceae	Alele
18	*Maesa lanceolata Forssk.*	Myrsinaceae	Abbayyii
19	*Millettia ferruginea (Hochst.) Bak.*	Fabaceae	Askra
20	*Olea capensis L.*	Oleaceae	Gagama
21	*Olea welwitschii (Knobl.) Gilg & Schellenb*	Oleaceae	Baya
22	*Pittosporum viridiflorum Sims*	Pittosporaceae	Sole
23	*Podocarpus falcatus (Thunb.) R. B. ex Mirb*	Podocarpaceae	Birbirsaa
24	*Polyscias fulva (Hiern) Harms*	Araliaceae	Kariyo
25	*Pouteria adolfi-friederici Rob. & Gilg*	Sapotaceae	Qararoo
26	*Prunus africana (Hook.f.) Kalkm*	Rosaceae	Oomoo
27	*Schefflera abyssinica (Hochst. ex A. Rich.) Harms*	Araliaceae	Botto
28	*Syzygium guineense (Willd.) DC. subsp. afromontanum F. White*	Myrtaceae	Bedessa
29	*Teclea nobilis Del.*	Rutaceae	Mixrii
30	*Vernonia amygdalina Del.*	Asteraceae	Ebbichaa

Appendixes 4: Families of woody species in coffee agroforests and natural forest

Coffee agroforests			Natural forest		
S/N	Families names	No. Species %	S/N	Families names	No. Species %
1	Fabaceae	15%	1	Araliaceae	8.33%
2	Araliaceae	10%	2	Boraginaceae	8.33%
3	Moraceae	10%	3	Euphorbiaceae	8.33%
4	Oleaceae	10%	4	Fabaceae	8.33%
5	Asteraceae	5%	5	Flacourtiaceae	8.33%
6	Boraginaceae	5%	6	Melianthaceae	8.33%
7	Euphorbiaceae	5%	7	Moraceae	8.33%
8	Flacourtiaceae	5%	8	Myrsinaceae	8.33%
9	Icacinaceae	5%	9	Oleaceae	8.33%
10	Meliaceae	5%	10	Pittosporaceae	8.33%
11	Melianthaceae	5%	11	Aquifoliaceae	4.16%
12	Myrsinaceae	5%	12	Asteraceae	4.16%
13	Myrtaceae	5%	13	Ebenaceae	4.16%
14	Pittosporaceae	5%	14	Icacinaceae	4.16%
15	Proteaceae	5%	15	Meliaceae	4.16%
16	Rosaceae	5%	16	Myrtaceae	4.16%
17	Rubiaceae	5%	17	Podocarpaceae	4.16%
18	Sapindaceae	5%	18	Rosaceae	4.16%
19	Simaroubiaceae	5%	19	Rubiaceae	4.16%
20	Ulmaceae	5%	20	Rutaceae	4.16%
			21	Sapotaceae	4.16%
			22	Simaroubiaceae	4.16%
			23	Ulmaceae	4.16%

Appendixes 5: Relative density, Relative dominance, Relative frequency and IVI of woody species in coffee agroforests

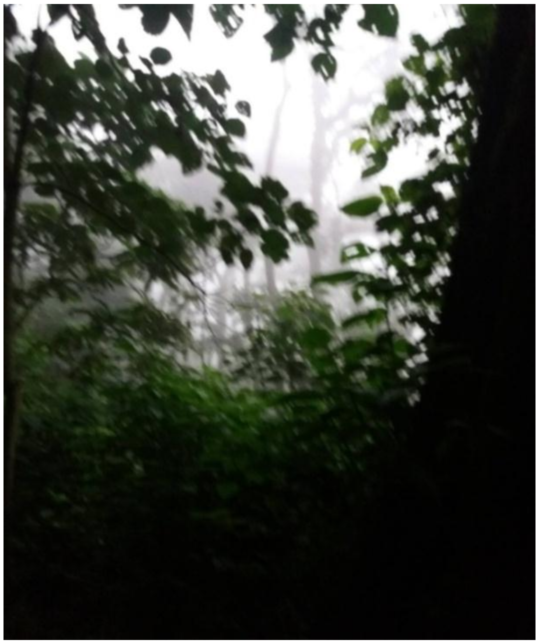
S/N	Botanical Name	Rel. Density	Rel. Dominance	Rel. Frequency	IVI
1	*Albizia gummifera*	12.66	18.62	10.16	41.44
2	*Millettia ferruginea*	13.97	8.01	13.36	36.34
3	*Croton macrostachyus*	15.72	4.95	12.82	33.49
4	*Cordia africana*	11.35	11.37	8.02	30.74
5	*Syzygium guineense*	6.55	5.81	8.02	20.34
6	*Polyscias fulva*	4.8	10.13	4.81	19.74
7	*Acacia abyssinica*	5.24	3.9	6.41	15.55
8	*Prunus africana*	2.18	6.32	2.67	11.17
9	*Schefflera abyssinica*	2.18	6	2.67	10.85
10	*Olea welwitschii*	2.62	4.4	3.2	10.22
11	*Apodytes dimidiata .*	2.18	3.46	2.67	8.31
12	*Ficus sycomorus*	0.87	6.36	1.06	8.29
13	*Allophylus abyssinicus*	2.18	3.36	2.67	8.21
14	*Galiniera saxifraga*	3.05	0.37	3.74	7.16
15	*Ekebergia capensis*	1.74	2.42	2.13	6.29
16	*Maesa lanceolata*	2.62	0.44	3.2	6.26
17	*Brucea antidysenterica*	2.18	0.29	2.67	5.14
18	*Grevillea robusta*	1.74	0.68	2.13	4.55
19	*Olea capensis*	1.74	0.26	2.13	4.13
20	*Ficus vasta*	0.43	2.64	0.53	3.6
21	*Celtis africana*	0.87	1.23	1.06	3.16
22	*Pittosporum viridiflorum*	0.87	0.51	1.06	2.44
23	*Vernonia amygdalina*	0.87	0.19	1.06	2.12
24	*Flacourtia indica*	0.87	0.14	1.06	2.07
25	*Bersama abyssinica*	0.43	0.06	0.53	1.02

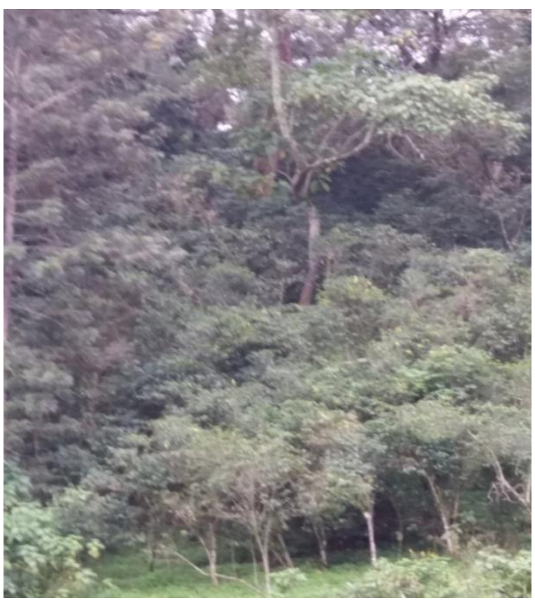
Appendixes 6: Relative density, Relative dominance, Relative frequency and IVI of woody species in natural forest

S/N	Botanical Name	Rel. Density	Rel. Dominance	Rel. Frequency	IVI
1	*Syzygium guineense*	10.68	14.19	9.54	34.41
2	*Schefflera abyssinica*	4.82	20.73	5.34	30.89
3	*Croton macrostachyus*	11.03	3.59	9.92	24.54
4	*Polyscias fulva*	6.55	9.47	6.48	22.5
5	*Prunus africana*	3.79	7.96	4.19	15.94
6	*Millettia ferruginea*	7.242	2.55	6.1	15.89
7	*Olea welwitschii*	3.79	8.51	3.43	15.73
8	*Pouteria adolfi-friederici*	2.06	10.51	2.29	14.86
9	*Olea capensis*	5.17	0.46	4.96	10.59
10	*Galiniera saxifraga*	5.17	0.53	4.58	10.28
11	*Teclea nobilis*	4.48	0.38	4.58	9.44
12	*Allophylus abyssinicus*	3.1	2.38	3.05	8.53
13	*Cordia africana*	2.41	2.47	2.67	7.55
14	*Ekebergia capensis*	2.75	1.65	3.05	7.45
15	*Ficus sycomorus*	1.37	4.36	1.52	7.25
16	*Podocarpus falcatus*	2.75	0.99	3.05	6.79
17	*Vernonia amygdalina*	2.75	0.57	3.05	6.37
18	*Flacourtia indica*	2.41	0.84	2.67	5.92
19	*Celtis africana*	1.72	1.9	1.9	5.52
20	*Maesa lanceolata*	2.06	0.21	2.29	4.56
21	*Bersama abyssinica*	1.72	0.51	1.9	4.13
22	*Erythrina brucei*	1.72	0.43	1.9	4.05
23	*Euphorbia abyssinica*	1.724	0.23	1.9	3.85
24	*Ficus vasta Forssk.*	0.68	2.35	0.76	3.79
25	*Pittosporum viridiflorum*	1.72	0.17	1.9	3.79
26	*Apodytes dimidiata*	1.37	0.59	1.52	3.48
27	*Brucea antidysenterica*	1.37	0.16	1.52	3.05
28	*Trema orientalis*	1.37	0.12	1.529	3.01
29	*Diospyros abyssinica*	1.37	0.005	1.52	2.89
30	*Ilex mitis Radlk.*	0.68	0.5	0.763	1.94

Appendixes 7: Regeneration status of woody species in coffee agroforests and natural forest

Coffee agroforests		Natural forest	
Botanical name	Regeneration status	Botanical name	Regeneration status
Acacia abyssinica	Poor	*Allophylus abyssinicus*	Good
Albizia gummifera	Good	*Apodytes dimidiata*	Poor
Allophylus abyssinicus	Good	*Bersama abyssinica*	Good
Apodytes dimidiata E..	No Regeneration	*Brucea antidysenterica*	Good
Bersama abyssinica	No Regeneration	*Celtis africana*	Good
Brucea antidysenterica	No Regeneration	*Cordia africana*	Good
Celtis africana	No Regeneration	*Croton macrostachyus*	Fair
Cordia africana	Poor	*Diospyros abyssinica*	Poor
Croton macrostachyus	Fair	*Ekebergia capensis*	Poor
Ekebergia capensis	No Regeneration	*Erythrina brucei*	Poor
Ficus sycomorus	No Regeneration	*Euphorbia abyssinica*	No Regeneration
Ficus vasta	No Regeneration	*Ficus sycomorus*	Poor
Flacourtia indica	Poor	*Ficus vasta*	No Regeneration
Galiniera saxifraga	No Regeneration	*Flacourtia indica*	Good
Grevillea robusta	Poor	*Galiniera saxifraga*	Good
Maesa lanceolata	No Regeneration	*Ilex mitis*	No Regeneration
Millettia ferruginea .	Fair	*Macaranga capensis*	No Regeneration
Olea capensis	Good	*Maesa lanceolata .*	Poor
Olea welwitschii	No Regeneration	*Millettia ferruginea*	Fair
Pittosporum viridiflorum	Fair	*Olea capensis*	Good
Polyscias fulva	Good	*Olea welwitschii*	No Regeneration
Prunus africana	No Regeneration	*Pittosporum viridiflorum*	Good
Schefflera abyssinica	No Regeneration	*Podocarpus falcatus*	No Regeneration
Syzygium guineense	Poor	*Polyscias fulva*	Poor
Vernonia amygdalina	Good	*Pouteria adolfi-friederici*	No Regeneration
		Prunus africana	No Regeneration
		Schefflera abyssinica	No Regeneration
		Syzygium guineense	Good
		Teclea nobilis	Good
		Vernonia amygdalina	Good






Coffee agroforestry and natural forest vegetation data collections

Material used for data collection

Household interview

Pictures show that a partial view of materials used for data collection and household respondents interview.