WOODY SPECIES DIVERSITY, REGENERATION, USES AND SOIL ORGANIC CARBON IN SEMI FOREST COFFEE AND NATURAL FOREST: CASE OF BELETE GERA FOREST PRIORITY AREA, SOUTHWEST ETHIOPIA

MSc THESIS

BY

KULENI FEKADU

NOVEMBER 2019
JIMMA, ETHIOPIA

Woody Species Diversity, Regeneration, Uses and Soil organic Carbon in Semi Forest Coffee and Natural Forest: The case of Belete Gera Forest Priority Area, Southwest Ethiopia

By

KuleniFekadu

MSc Thesis

Submitted to the School of Graduate Studies Jimma University, College of Agriculture and Veterinary Medicine in Partial Fulfillment of the Requirements for the Degree of Master of Science in Natural Resource Management Specialization in (forest and nature conservation)

Major Advisor: Mr. Zerehun Kebebew
Co-advisor: Mr. Hirko Dibaba

November 2019
Jimma, Ethiopia

DEDICATION

I dedicate this thesis manuscript to my mother EbiseEtefa and my father FekaduChewaka for their dedicated partnership in the success of my life.

STATEMENT OF AUTHOR

I hereby declare that this thesis entitled; **Woody Species Diversity, Regeneration, Usage and Soil Carbon Stock in Semi Forest Coffee and Natural Forest: The case of and Soil Carbon Stock in Semi Forest Coffee and Natural Forest: The case of Belete Forest Priority Area, Southwest Ethiopia**, is my original work and has not been submitted in any University and all the sources of materials used for the thesis are duly acknowledged. The thesis is deposited at the Jimma University Library to make available to borrowers under the rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate

Name: Kuleni Fekadu

Signature___________

Place: Jimma University

Date of submission:____________________

BIOGRAPHICAL SKETCH

The author, Kuleni Fekadu, was born on Dec 1986 in Seka town, Jimma Zone, Oromia National Regional State (ONRS), Ethiopia. She attended her primary and junior secondary school in Seka primary and secondary school and completed. Diploma program Agarfa TVET College and after six year service She joined Jimma University in 2007 and graduated with Bachelor's Degree in Natural Resource Management Studies in 2012. Upon her graduation, she was recruited by ONRS, Jimma zone Shabe Sombo woreda

Agricultural and Rural Development Office as an expert of Forest conservation department in 2012. After five years of service, she joined Jimma University in 2018 to pursue her post-graduate study to M.Sc. degree in Natural Resource Management (specializing in Forest and Nature Conservation).

ACKNOWLEDGEMENTS

Above all, I would like to thank and respect Almighty God for his endless support and nothing happened without his knowledge.

I would like to express my special indebtedness to my advisors Mr. Zerehun Kebebew and Hirko Dibaba for their persistent help in all the steps of the thesis. Their guidance and inspiration made this study a reality. My understanding of the subject matter grew from the frequent discussions made with them. Thank you, my advisors for your guidance, encouragement, unwavering support and willingness to share your area of expertise. Once again, I would like to pass my heart-felt appreciation and respect for Mr. Zerehun Kebebew as a most important individual for his recommendation writing for Idea Wild organization that fortunate me of material funding.

I would like to thank all individuals and organizations who have contributed any kind of support in the process of carrying out this research. My thanks extend to Agricultural and Rural Development Office support and encouragement, and Idea Wild organization for material fund.

My deepest appreciation goes to my Father Fekadu Chewaka and my mother Ebise Etefa for their unreserved care, love and encouragements throughout my study. I am very much grateful to whole members of my families, for their continued moral support and encouragement in the course of this study. And to my friends (Murad A/Mecha, Mamed A/Gisa and Abdo) who contributed for the success of the study.

My special thanks also go to key informants and respondent households in the study area for their kind respect and permit to collect data. I am thankful to the contributions of development agents, local guides, and enumerators.

LIST OF ACRONYMS

FAO	Food and agricultural organization
ICO	International coffee organization
SFC	Semi forest coffee
EPA	Environmental protection authority
WFP	World food program
UNDESA	United Nations Department of Economic and Social Affairs
IUFRO	International union of forest research organization
NTFP	Non timber forest product
BGRFPA	Belete-Gera Regional Forest Priority Area
FC	Forest Coffee
SEPSHSD	Socio economic profile of Shabe Sombo district Report
SHSWRLEP	Shabe Sombo Woreda Rural Land and Environmental protection
GPS	Global positioning system
DBH	Diameter at breast height
CAFs	Coffee agro forests
CSA	Central Statistical Agency
AFPs	Agro forestry practices
NF	Natural forest
SOC	Soil organic carbon
OC	Organic carbon
HH	House holds

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (*Continued)*

TABLE OF CONTENTS (*Continued*)

LIST OF TABLES

PAGE

LIST OF FIGURES

PAGE

LIST OF APPENDIX

PAGE

ABSTRACT

A coffee agroforest has been promoted as means of preserving biodiversity in the tropics. Therefore, this study was conducted on diversity, regeneration, usage of woody species and soil organic carbon under SFC and natural forest of Belete forest priority area, south west, Ethiopia. To conduct the study, 60 plots (30 from natural forest and 30 from semi forest coffee) samples were taken using simple random sampling methods. And a total of 60 soil samples were collected from the two site and SOC, soil texture, bulk density and pH were analyzed. Household survey was conducted to collect woody species usage under natural forest and SFC. A total of 120 households (60 households for each sites) were randomly selected for the interview on usage of woody species through semi-structured interviews. The vegetation data was analyzed for woody species diversity, Importance value index, similarity coefficient, density and basal Area, regeneration and usage parameters. A total of 47 woody species were recorded belonging to 24 families in natural forest and 34 woody species belonging to 17 families in SFC were identified and recorded. Although more woody species were recorded under the natural forest, the difference was not statistically significant ($p>0.05$).The difference in species richness and Shannon diversity index of woody species between natural forest and semi forest coffee were also not statistically significant ($p>0.05$). Regeneration status of seedling and sapling of woody species had showed significant ($P<0.05$) differences between the natural forest and semi forest coffee. However, there was no statistically significant difference ($p > 0.05$) between the natural forest and semi forest coffee interms of tree density. The conservation practices and usage of woody species under the natural forest and semi forest coffee are the same. It was observed that tree species diversity and Household (HH) dependency on coffee production increased with the closeness of the adjacent natural forest. Soil carbon was analyzed in laboratory. The SOC under the native forest was 51.35 ± 0.11and 50.64 ± 0.08 under the semi forest coffee. Native forest and semi forest coffee had no significant difference by its SOC. It is concluded that woody species management practices in the study area of semi-forest coffee farms more or less the same to the adjacent natural forest. So semi-forest coffee has to be promoted as the main land use system in minimizing woody species loss with continuous monitoring of the forest area.

Key Word: Woody Species, Diversity, Uses, Soil Organic Carbon

1. INTRODUCTION

1.1 Background and justification of the study

The practice of tree integration in coffee production systems plays a very important role in biodiversity conservation (Correia *et al.* 2010). In Ethiopia, the moist montane forest has long been recognized as the center of origin and diversity of wild *Coffeaarabica* L. (Senbeta *et al.*, 2005). Even though coffee is under story woody shrub, expansion of coffee cultivation is one of the causes of deforestation and biodiversity loss (Ambinakudige and Sathish, 2009).However, Agro-forestry systems are widely seen as the means that can reduce the impacts of deforestation (Tengnas, 1994) through providing eco-agricultural solutions that successfully combine objectives for increased food security and biodiversity conservation gains (Kindt *et al.*, 2008). For instance, coffee shade systems host diverse plant species (Ambinakudige and Sathish, 2009). Accordingly, traditional shaded coffee production system have received considerable attention from conservation organizations in recent years (Perfecto *et al.*, 2005) since the system supports much more biodiversity conservation and cash income generation from the sale of both timber and non- timber forest products (Gordon *et al.*, 2007).

Agroforestry practices (AFPs) vary in their composition, structure, and function depending on the biophysical, ecological, social, economic and cultural condition under which they occur (Omer, 2018). Especially in developing countries the trade-offs between socio- economic goals of increasing rural incomes and decreasing poverty and environmental goals such as biodiversity conservation are large (Bekessy *et al.*, 2010).Coffee is produced under four different production systems, along an intensification gradient: forest coffee accounting for 10% of total coffee production; semi-forest coffee accounting for 35%; garden coffee for 50%; and plantation coffee for 5% (Kufa, 2012).

Semi-forest coffee is produced in relatively disturbed natural forests where the upper canopy is thinned and coffee is sometimes randomly planted in the forest to increase the number of shrubs and coffee yields (Gole *et al*., 2008). Farmers usually slash undergrowth once a year to reduce competition for soil nutrients with other species. It has been estimated that in the last four decades in Southwestern Ethiopia, the conversion of forest coffee to semi-forest coffee resulted in a 34% reduction in woody forest species (Tadesse *et al*., 2014). In addition to this

Coffee intensification and coffee expansion are responsible for substantial forest cover loss in Ethiopia. For instance, in the coffee growing areas in the southwest Ethiopia, deforestation is estimated at 10,000 ha/year (Tadesse *et al*., 2002). Thus, this situation led to forest degradation which may result in Carbon emission to the atmosphere. Thus, there is a need for developing sustainable systems to maintain and improve SOC content while mitigating land degradation and greenhouse gas emissions. However, numerous studies have indicated the importance of coffee agroforests for biodiversity conservation (Gordon *et al.,* 2007; Mendez *et al.* 2010; Dawson *et al.* 2013; Pinard *et al.,* 2014) and Adopting agro forestry related practices is among one of the promising management practices to increase biomass and SOC stocks, and thereby reduce soil degradation and mitigate climate change (Batjes and Sombroek, 1997). Soil carbon sequestration constitutes one of realistic option achievable in many agro forestry systems.

According to Hylander (2013) southwest Ethiopia has a lower rate of deforestation in coffee growing areas than in other areas. If this situation continues, the current configuration of a coffee-tree system would represent an important change in land-use strategy to retain the landscape’s ecological process and integrity, while farmers receive socioeconomic benefits. Nevertheless, the very low densities of tree species reported in other studies (Correia *et al.,* 2010) are still critical.

Indigenous communities have been utilizing wild coffee for centuries, and the art of brewing coffee is a central element of the Ethiopian culture. Furthermore, coffee is Ethiopia’s most important export crop contributing 41% of the country’s foreign currency income (FAO & WFP, 2006). Despite of its vital role for biodiversity conservation in tropical country, in Ethiopia the contribution of coffee agro forests and natural forest on biodiversity conservation aspects have less emphasis and documentation. Belete forest is one of piloted forest under participatory forest management approach. Participatory forest management is the approach to manage, the remaining forest of Ethiopia. But, from time to time forests which they regularly use are declining through different anthropogenic activities including agricultural expansion, overexploitation, human encroachments and settlements, the expansion of large commercial farms in forest areas (especially through semi forest coffee and plantations coffee system) (EPA,2003; MELCA Mahiber, 2008).

In the 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). Previous studies in southwest Ethiopia have focused on comparative ecological differences between the natural forest and coffee agroforestry (Senbeta and Denich, 2006; Wiersum *et al.,* 2008; Aerts *et al.,* 2011; Hundera *et al.,* 2013). Some findings have shown that modifying the natural forest for coffee production has reduced the floristic diversity and specific functional groups (Senbeta and Denich, 2006). However, the role of semi-forest coffee adjacent to the natural forest in conserving woody species, providing deferent uses from woody species, mitigating land degradation and greenhouse gas emissions through improving SOC and reducing pressure on the natural forest are less studied. The changes in patterns of population structures, regeneration and diversity could provide valuable information for conservation strategies. Therefore, this study was aimed at providing relevant information, which is of paramount importance to undertake on diverse range of woody species usage and changes in ecological information due to over exploitation about the natural forest and semi-forest coffee necessary to design suitable conservation and sustainable use approaches. In addition, provide information about forest product and its access.

1.2. Objectives of the study

1.2.1. General objective

The overall objective of this study is to asses and compares Woody species diversity, regeneration, uses and soil carbon stocks in semi forest coffee and natural forest around Belete Gera forest priority area.

1.2.2. Specific objectives

- ✓ To asses and compare woody species diversity between semi forest coffee and natural forest.
- ✓ To asses and compare regeneration status of tree species on semi forest coffee and adjacent natural forest around Belete forest priority area.
- ✓ To investigate patterns of woody species uses in semi forest coffee and adjacent natural forest around Belete forest priority area.

- ✓ To compare soil organic carbon in semi forest coffee field and native forest land use systems.

1.3. Research questions

This study addressed the following research questions:

- Do Semi-forest coffees maintain comparable diversity and composition with that of adjacent natural forest?
- How do woody species regeneration of semi-forest coffee compared with adjacent natural forest?
- Do woody species usage from the semi forest are comparable with that of adjacent natural forest?
- How the semi-forest coffee and natural forest varies in their soil organic carbon?

1.4 Significance of the study

In Ethiopia the lives of many rural communities directly related to natural resources, forest means everything and thus all efforts towards conservation of natural resources and sustainable use of its products is a challenging task (Regassa, 2001). From those challenging tasks, expansion of coffee agro forestry to the natural forest area is major one in Belete forest priority area. In addition, there is a change in activity use of woody species products. And currently the demand of reliable information regarding soil organic carbon at both country and global levels is growing (Genene *et al.*, 2013). So the significance of this activity use of woody species and soil organic carbon knowledge is important in appropriate conservation strategy. Thus, this study is important to show how the use , ecological information of woody species and soil organic carbon under semi-forest coffee and adjacent natural forest to conservation sectors of government and other related stakeholders for the sustainability of those woody species resources.

2. LITERATURE REVIEW

2.1. Biodiversity use and conservation

Biological diversity refers to the variability among living organisms from all sources, including, *inter-alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Heywood, 1995). Management of agroecosystems for biodiversity conservation is increasingly recognized. Agro forestry systems in particularly provide a refuge for forest dwelling organisms (Bhagwat *et al*. 2008; Dawson *et al.* 2013). Their suitability for biodiversity conservation is, however, affected by management intensity and canopy cover (Tejeda-Cruz and Sutherland 2004; Bhagwat *et al*. 2008), and there are tradeoffs between income, biodiversity and ecosystem functioning during agro forestry intensification (Steffan-Dewenter *et al*. 2007; Philpott 2010). Numerous studies have indicated the importance of CAFSs for biodiversity conservation (Gordon *et al.* 2007; Mendez *et al.* 2010; Dawson *et al.* 2013; Pinard *et al.* 2014). For instance, diverse polyculture coffee farms in Mexico are richer in tree species than other coffee agro forests and nearby forests (Dawson *et al.* 2013).

Various plant species have different uses depending on socio-economic conditions of a given community. From those species woody species in natural forests are important sources of forest products such as fruits, fodders, honey, herbal medicine, a source of tools and construction materials, timber and food for local communities. Such unsustainable utilization of few species especially, for timber and fuel wood collection put them in the endangered category. Also natural forest has wide ecological and environmental values and is a source of biodiversity (Bekele, 2016). From those values the need for fuel wood, farm land, human settlement, shifting cultivation, grazing area, firewood, lack of viable land policy have been indicated as the main cause for forest biodiversity degradation frequently leading to loss of forest cover and biodiversity loss (Ensermu and Teshome, 2008).Particularly, the current contributor factors accelerated the declining of woody plant species diversity in Ethiopia are the size and distribution patterns of humans and domestic animal populations, the level of resource consumption, understanding woody plant species in narrow sense due to low level of awareness, the attention of woody plant species conservation and sustainable use has so far been inadequate (Tesfaye, 2007).

To meet those requirements precise and up to date information regarding the status of the forest resources and potential of forest regeneration in poorly managed forest is important to upgrade and to design proper management for future improvement of the forest stand. The better we understand the forest the better we will be able to protect, conserve and manage them (Sandalow, 2000).In order to understand what is truly happening we need to monitor the resource to measure and predict change (IUFRO, 1995). Sustainable forest management has been the main focus of the worldwide forestry sectors over many years. It aims to ensure that needs derived from the forest meet present day needs without comprising the ability of future generation. Sustainable forest management also aims at balancing social, economic and environment as objectives. In general agro forestry plays a roles of providing habitat for species that can tolerate a certain level of disturbance, reduce the rate of conversion of the natural habitat and providing connectivity by creating corridors between habitat remnants (Boffa et al,2005).This approach focuses on sustainable conservation and utilization of the species.

2.2. Agro forestry concept and its role in conserving woody species

Agro forestry is a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefit for land users at all levels (Asfaw, 2016). Traditional coffee agro forests incorporate shade trees in order to retain ecosystem services such as soil fertility, wood and non-wood products. Coffee agro forestry systems can potentially protect biodiversity by providing heterogeneous and critical habitats, buffer against overexploitation of forest biodiversity, and serve as corridors and permeable matrixes that connect meta-communities in natural landscapes (Perfecto *et al.*, 1996). Coffee landscapes may have greater conservation potential in hyper-fragmented landscapes with long histories of human use and disturbance since much of the original forest vegetation is lost and modified.

Besides home-garden coffee and coffee plantations, almost 70% of the coffee production area in Ethiopia still consists of montane rainforest with wild coffee (Teketay, 1999). The harvesting of wild coffee inside the forest is carried out at different use intensities; local farmers may simply pick wild coffee fruits while occasionally removing some of the undergrowth vegetation to facilitate coffee collection. The forest retains a virtually undisturbed vegetation structure and can be considered as natural or unmanaged forest. There are also more intensively managed forest parts where farmers systematically remove some of the shading canopy trees and undergrowth vegetation that competes with wild coffee. These forest areas have a disturbed forest structure and are known as semi-forest coffee (SFC) systems.

The management interventions in SFC systems also had strong impact on tree species composition; especially in the upper canopy. And the expansion of SFC systems is likely to enhance the modification and loss of the natural rainforest vegetation in southwestern Ethiopia. This is also a danger in the study region, where<10% of the land cover can still be considered as natural forest (Schmitt, 2006). This activity might affect and limit the number of woody species which are grown in system (Mangistu and Asfaw, 2016). But when compare with other activities a recent study in southwest Ethiopia showed a lower rate of deforestation in coffee growing areas than in other areas (Hylander*et al.* 2013).In addition to this the role of agro forestry to food security and climate change goals is magnificent (Mbowet al. 2014). Agro forestry can provide economic and environmental benefits and is considered a win-win practice through which communities can adapt and become more resilient to the impacts of climate change (Nair 1998; Acharya and Kafle 2009; Kumar, 2015).

According to (Kitessa, 2016) there is a traditional practice of forest management in coffee producing communities in Ethiopian moist Afromontane forests to increase coffee production. The practice involves removal of big canopy trees with excessive shade and selectively retaining specific tree species as preferred shade trees. Due to these selective thinning very few or limited tree species are grown on the larger area without competition. In addition to this, farmers cut matured and aged tree species which grown in the farm for the construction (timber) purpose. And, in order to produce suitable environment for the growth of major species (e.g. Coffee), the regeneration and density of other species were affected by human activity. And conserve some tree species due to the benefits gets from them, such as honey extraction, extraction of other NTFP etc (Kitessa, 2007).However, the success or failure of tree species conservation in coffee agro ecosystems are influenced by Social, economic, and political factors (Somarriba *et al.*, 2004).

2.3. Woody species uses and conservation

The livelihood of the community living inside and around the forest depends in various ways, on the products and services provided by the diversity of trees (Cavendish, 2002; 2007; McElwee, 2008). There has been increasing encroachment on the shade trees and the natural forest reserve. Due to this high demand the forest is threatened in un sustainable harvesting of forest products. But agro forestry systems are widely seen as the means that can reduce the impacts of deforestation (Tengnas,1994) through providing eco-agricultural solutions that successfully combine objectives for increased food security and biodiversity conservation gains (Kindt *et al*. 2008). The identified use categories include food, medicine, honey, material sources, social services, animal fodder and environmental uses .Hence promotion of this valuable indigenous knowledge can make an important contribution to alleviation of rural poverty by improving food security and economic welfare of rural population (Fayera, 2013).

In addition to the above-mentioned values, tropical forests have also recreational, eco-tourism and ecosystem conservation values (Gaston and Spicer, 1998). In these forests, woody species are the most important components, from the ecosystem point of view, influencing the variability and living conditions of other forest organisms (Burianek, 1998). Decrease in woody species diversity can, thus, impoverishes other groups of organisms. For instance, coffee shade systems host diverse plant species (Ambinakudige and Sathish, 2009). Accordingly, traditional shaded coffee production system have received considerable attention from conservation organizations in recent years (Perfecto *et al.* 2005) since the system supports much more biodiversity conservation (Perfecto *et al*. 2005; Gordon *et al*. 2007) and cash income generation from the sale of both timber and non- timber forest products (Gordon *et al.* 2007).

The Arabica coffee which is produced under the shade trees is most important source of foreign currency for many developing countries. Seventy per cent of the world's coffee is contributed by smallholders in developing countries who grow coffee mostly on farms of less than 5 hectares and intercrop coffee with other crops (Mohan and Love, 2004).The agriculture-based Ethiopian economy is highly dependent on *Coffeaarabica*(Gole *et.al.*, 2002). It plays a fundamental role both in the cultural and socio-economic life of the nation.

According to Gardei (2006), the majority of farming communities in Southwest Ethiopia are forest dependents and major source of their livelihood and subsistence were depending on providing variety of forest products. According to Hana (2016), more than 65 percent of the households who are 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.

2.4 Soil organic carbon

Ethiopia is one of the countries most affected by land degradation in sub-Saharan Africa (Nedessa *et al.* 2005; Abesha 2014). Therefore, understanding the fundamental social and ecological drivers of land degradation (Aynekulu *et al*. 2006) with possible solutions including rehabilitation of degraded areas (Girmay *et al.* 2008) is critical. Conversion of land from native forests to agricultural ecosystems is known to change both biomass and soil organic carbon (SOC) pools. The effect of land use change on soil properties may vary for different soils, vegetation types and ecological zones (Bekele, 2006).The importance of agro forestry as a land-use system is receiving wider recognition in terms of both agricultural sustainability and also in issues related to climate change (Albrecht and Kandji, 2003). So adopting agro forestry related practices is among one of the promising management practices to increase biomass and SOC stocks, and thereby reduce soil degradation and mitigate climate change (Batjes and Sombroek, 1997).

Forest ecosystems store more than 80% of all terrestrial aboveground Carbon and more than 70% of all soil organic Carbon (Batjes, 1996; Jobbgy and Jackson, 2000; Six *et al.*, 2002).As some studies indicated, the overall land-use systems can be ranked in terms of their SOC content in the order: forests >agro forests> tree plantations > arable crops (Nair *et al.*, 2009).According to Albrecht and Kandji (2003) SOC in the top one meter of the world soil comprises about three over four of the earth's terrestrial carbon; and there is also tremendous potential to sequester additional carbon in soil. Management systems that add high amounts of biomass to the soil, causes minimal soil disturbance, improve soil structure, and enhance soil fauna activity (Lal *et al*., 2004). Key factors in the efficient sequestration of more carbon in the soil are likely to be the starting content of SOC, the soil type, and balance between the addition of plant residues and the mineralization of SOC. However, there are as yet relatively few studies that assess effectiveness and adoption SOC stock (Bangroo *et al*., 2011).Deforestation can release large quantities of Carbon, and afforestation can fix CO2 in new biomass and dead organic matter. These changes in land use are regionally of different relevance.

In agro forestry systems, there are both ecological and economical interactions between the different components (Lundgren and Rain tree, 1982 cited by Nair, 1993).Integration of trees, shrubs, crops, pasture and livestock components intentionally in agricultural practices are a common characteristic feature in all forms of agro forestry systems (Young, 1997; Nair, 1993). These components together with the other factors such as climate, soil, and landform are the main components of agro forestry systems (Young, 1997).Agro forestry systems have the potential to sequester atmospheric carbon (C) in vegetation and soil while maintaining sustainable productivity. It is also one of the promising management practices to reduce soildegradation (Lal, 2004).

Agro forestry has a particular role to play in mitigation of atmospheric accumulation of carbon dioxide for instance, as reported by different scholars Land-Use Change and Forestry report of the IPCC, agro forestry offered the highest potential for carbon sequestration (Nair *et al.*, 2009). Trees also provide various service functions, such as increasing soil organic matter and nutrient levels and reducing runoff and soil loss, and these increase the productivity of fields beyond what occurs in fields without trees. Land misuse and soil mismanagement has caused depletion of SOC with an attendant emission of CO_2 and other GHGs in to the atmosphere (Lal, 2004). Carbon is lost from the soil through leaching of dissolved carbon, erosion, and conversion of carbon to carbon dioxide through mineralization (Baldock, 2007).

3. MATERIAL AND METHODS

3.1. Description of the Study Area

3.1.1 Location of the area

The study was conducted at Belete forest, which is part of Belete Gera RFPA located in ShabeSombo district of Jimma Zone, southwestern Ethiopia. The woreda is located at 375 km south west of Addis Ababa and it is part of the Belete Gera National Forest Priority Area and Situated at longitudes between 36015'E and 36045' E and latitudes 7030' N and 7045'N .

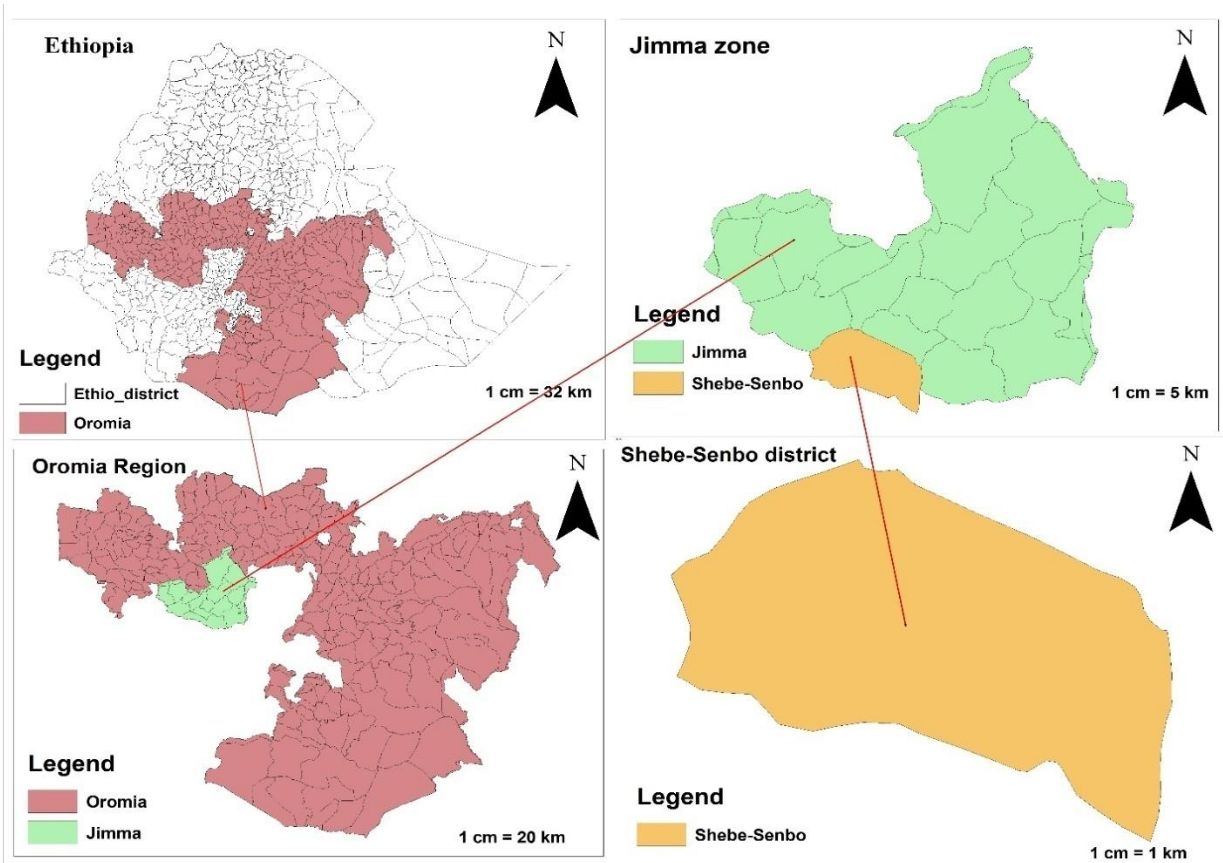


Figure 1. Map of the study area

3.1.2. Agro-ecology

Agro-climatic zones of shabesombo are lower altitude 20%, middle altitude 65% and high altitude 15%.

3.1.3 Climate

The area receives an average annual rain fall ranging from about 900 to 1300mm. The minimum and maximum daily temperatures of the area are 20°C and 28°C, respectively (Abazinab *et al.,* 2017).

3.1.4 Economy

In Shabe-Sombo Woreda, the economic base of the people is directly linked to agriculture, mainly production of food crops followed by coffee and rearing of livestock. The major cereal crops produced in the area include maize, wheat, barley and teff. And; the livestock are cattle, sheep, goats, horses and poultry. In addition honey production, natural coffee and firewood gathering from the forest is used for income generation. Belete-Gera forest is under Participatory Forest Management regime commenced in 2007. Community-driven forest management associations; improving agricultural technologies and practices through farmer field schools and livelihood support through the Forest Coffee Certification Program.

Forest Coffee Certification Program supported producers of forest coffee in obtaining forest coffee certification from the Rainforest Alliance, a US-based NGO. The price of certified coffee at the farm gate is 15-20 percent higher than the regular price. Coffee certification program is an effort to encourage shaded coffee system to move toward greater sustainability (Mas and Dietsch 2004). According to JICA (2010), providing premium price to producers who maintain shade coffee successfully enhanced the incentive of conserving forest areas and biodiversity offer an opportunity to link environmental and economic goals.

Table 1 Land use types for Shabe Sombo district

Land use types	Area in(ha)	%age
Cultivated land	40014	33.59
Grazing land	490	0.41
Forest land	51000	42.82
Settlement land	8696	7.30
Wet land	2798	2.35
Others	16102	13.52
Total	119100	100

Source: SEPSh.SD Report 2016, ShSWRLEP Office 2017

3.1.5. Vegetation

The total area of Belete forest is about 25,597.94 ha. The natural forest account for 16312.96 ha whereas the coffee area is about 9284.98 ha (JICA, 2010). The forest cover has declined 40% between 1985-2010 periods (Todo and Takahashi, 2011). In addition, the forest is heavily disturbed by human activities like selective logging, livestock grazing and coffee production (Cheng *et al*., 1998). Belete forest is characterized as an Afromontane evergreen forest, dominated by trees like *Syzigiumguineense, Olea welwitschii, Prunus africana* and *Pouteriaadolfi-friederici (*Demissew *et al*., 2004).

Even though, the majority of the natural forests are under the government protection it is presently under great threat because of over exploitation (Hundera, 2007). In the area, forests are mostly used by local communities, and large-scale commercial logging is not present. Different researchers, the forest managers and experts raised three major reasons for the rapid declining of forest in the area: expansion of farmland including planting coffee into the forest; wood extraction for home consumption and commercial sales of firewood and timber; and illegal settlement by migrants from other regions of Ethiopia due to the country's growing population and different man-made/ natural hazards. Although wood extraction is illegal in the forest area, which is owned by the government, it is difficult to prevent, as there had been no active system or institution for forest management, either community or government- driven(Todo and Takahashi, 2011).

3.1.6 Population

Total populations of the district are 134,442. From these 67,866 (51%) were males and 66,576 (49%) female (CSA, 2014). Forest area 7983 households live a total population around 8,571. About 76.83% are Muslim, while 21.26% Orthodox Christianity and 1.77% were Protestant. Its administrative center is Shabe town.

3.1.7 Topography of the area

Belete forest area was dominated by gentle slopes and a localized steep slopes ranging from 4 - 45%. Several small streams cross the area. It is bordered on the south and south-east by the Gojeb River which separates it from the SNNPNRS, on the west by Gera Woreda and on the north by Seka Chekorsa Woreda. The altitude ranges between 1,300 and 2,900 masl.

3.2 Research Methodology

3.2.1 Sampling method

Two sites (Sebeka Debiye and Shabe Daso) were selected purposively due to the presence of semi forest coffee and natural forest, relative proximity to road and nearby forests from seven village bordering the natural forest. The household for forest inventory were selected ten households from each of the wealth categories (in generally 30 households) based on the criteria, such as the amount of coffee and cereal crops produced in quintal per year, livestock holding and type of house, educating daughters etc. The households for interview were selected based on simple random sampling techniques. The sample size was determined using the formula following Barlett *et al*. (2001) and decided proportional to the total population size. Accordingly, a total of 120 households were sampled for this study from those who has semi forest coffee.

$$n_o = \frac{z^2 * (p)(q)}{d^2} \quad n_1 = \frac{n_o}{(1+\frac{n_o}{N})}$$

Where;
no= Desired sample size when population greater than 10,000

n1= Finite population correction factors less than10, 000

Z = Standard normal deviation (1.96 for 95% confidence level)

P = 0.1 (proportion of population to be included in sample i.e. 10%)

q = 1-P i.e. (0.9)

N = Total number of population
d = Degree of accuracy desired (0.05)

Table 2 Sample size determination of households

Name of kebele	Total household	Sample size
ShabeDaso	698	62
Sebeka Debiye	540	58
Total	1238	120

3.2.2 Vegetation data collection

Vegetation data were collected from the farm of the house hold adjacent to the natural forest and from the adjacent natural forest. A total of 60 plots (30 plots for natural forest and 30 plots for semi forest coffee) with an area of 20 m x 20 m have been established. The plots of 20m x 20m were established at the center of the farm (one plot per farm) and the adjacent natural forest. Within the main plots, a subplot of 10 m x 10 m and 5 m x 5 m were nested for saplings and seedlings assessment respectively. To avoid edges effects all sample plots were established at least 50 m from forest edges or roads inside the forest (Senbeta and Teketay, 2001).

Measurement on tree species of diameter at breast height >5cm and height of >3cm has been conducted in each plot (Mekonnen *et al.,* 2018). Diameter measurement was done using diameter tape. All woody species were identified by local name (Afan Oromo) with the help of local community 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).

3.2.3 Woody species uses information data collection

Woody species usage was collected on the benefits of woody species of natural forest and semi forest coffee of households. It focused on household's characteristics (Rich, medium and poor households). Structured and semi structured questionnaire were prepared to collect the information. Information was collected through household interview.

3.2.4 Soil sampling method

Soil samples were taken from plots of 20 m x 20 m which was used for vegetation survey. Two types of soil samples were taken; one for bulk density by using a core sampler, and the other for chemical analysis by using soil auger. The soil data was obtained through gathering 60 composite samples (30 from SFC and 30 from NF) at 30cm depth .The soil samples from the four corners and at the center of the plots was composited and brought to Jimma University Soil Laboratory Center, which is located at Jimma, Jimma Zone, Southwest Ethiopia.

3.3 Methods of data analysis

3.3.1. Species accumulation curve

The total numbers of plots were checked by drawing the species area curve. The species accumulation curve is concerned with accumulation rates of new species over the sampled area and depends on species identity. Species accumulation curve was draw to check total sample size taken for woody species assessments. The AccuCurve is a Microsoft Excel 2003 based program calculating various accumulation curves for a set of samples containing more species (Drozd and Novotny, 2010).

All individuals of species registered in all the sample quadrates were used in the analysis of diversity, frequency of disturbance, and regeneration status. The Diameter at Breast Height (DBH), basal area, tree density, frequency and important value index is used for description of vegetation structure.

3.3.2 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 (Magurran, 2004):

$$H' = -\sum_{i=1}^{S} P_i \, lnP_i$$

Where: H`= Shannon diversity index

Pi = proportion of individuals found in ith species

A. Diameter at Breast Height (DBH)

DBH measurement was taken at about 1.3 m from the ground using common tape. Like caliper, the common tape does not measure diameter directly, but instead measures the circumference of the tree.

The circumference was converted to diameter by solving for DBH in the equation: C = π* DBH.

Where: C =circumference of tree, π=3.14... ,

DBH =diameter at breast height of tree.

Therefore, DBH = C/π …………………………………...........…. (FFA Forestry, 2010)

B. Basal Area (BA)

Basal area refers to a measure of tree density that defines the area of a given section of land occupied by the cross-section of tree. The relative importance of woody species in a forest is well understood from measurements of basal area than stem counts. Therefore, species with the largest contribution in basal area considered the most important woody species in the forest (Fekadu *et al.,* 2012). It expressed in meter square per hectare. Basal areas were also used to calculate the dominance of species.

BA= Π (D/2)2= (DBH/2)2X3.14... (Suratman, 2012).

Where

BA- Basal Area (meter square)

D (DBH) -is diameter at breast height (cm)

Π= 3.14

C. Shannon evenness (E): is the distribution of individuals among the species in a studied forest.

$$E = \frac{H'}{H'_{max}} = \frac{\sum_{i=1}^{s} P_i \, lnPi}{lns}$$

Where: E= Equit ability (evenness) which was values between 0 and 1 H`= Shannon diversity

H`max= Maximum level of diversity possible with a given population

Pi= Proportion of individuals found in ith species

S= Total number of species (1, 2, 3 ….S) source (Kent and Coker 1992)

D. Sorensen's similarity index: is the common similarity measurement index, which ranges from zero (no species in common) to one (identical set of species).It was calculated to indicate that the degree of similarity in composition of woody species between natural forest and semi-forest coffee. It is calculated with the following formula (Magurran, 2004):

$$S_s = \frac{2C}{(2C + A + B)}$$

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.

E. Important value index (IVI)

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

IVI= Relative dominance + Relative frequency +Relative abundance

F. Dominance

It refers to the degree of coverage of a species as an expression of the space it occupied in a given area.

Dominance =<u>Total basal area</u>

Area sampled

Relative dominance =<u>Dominance of species A</u> * 100

Total dominance of all species Source (Kent and Coker, 1992).

G. Frequency: it shows the presence or absence of a given species within each sample plot.

Frequency of species = <u>No. of plot that species occurs</u> * 100

Total number of plots

Source: (Moreno-Casasola *et al.*, 2011).

Relative frequency= <u>Frequency of species A</u> * 100

Total frequency of all species

H. Abundance

Relative Abundance =<u>Number of individual of species</u> * 100

Total number of individuals **Source:** (Magurran, 2004).

I. Density

The density of woody species has been 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:

$$\text{Density} = \frac{\text{Total number of individuals}}{\text{Sample area in ha}} * 100$$

3.3.3 Woody species statistical data analysis

In this study, the collected data from woody species inventory and household questionnaires were coded, computerized and analyzed using the Microsoft Excel and Statistical Package for Social Sciences (SPSS) version 20 for different statistical purpose. T-test were used to compare forest products utilization and status of forest differences of the natural forest and semi-forest coffee.

3.3.3 Soil laboratory Analysis

The samples collected for chemical analysis were dried by air, crushed the clods by hand to accelerate the drying process, grinded by mechanical grinder and sieved by a 2 mm sieve mesh. The samples were analyzed for C, pH and textural analysis. Soil pH was measured potentio metrically using a pH meter a 1:1 (v/v) soil water suspension and textural fraction was determined by hydrometer method. The soil samples taken for bulk density calculation were oven dried at 105°C for 24 hours. In this study it was calculated as oven dry weight mass (g) divided by sample volume (cm3) (Pearson *et al*., 2005) method. SOC was analyzed according to Walkley-Black method (Walkley and Black, 1934).

3.3.4 Soil statistical data analysis

The results were subjected to analysis of variance (ANOVA). All statistical computations were made by using the statistical package for social sciences (SPSS version 20). The least significant difference (LSD) at $P \leq 0.05$ was used to determine statistically significant differences within each variable. The significant difference at $P>0.05$ was used to determine statistically significant differences between natural forest and semi-forest coffee. We conducted one-way ANOVA test for significant differences in SOC for each category of land uses.

4 .RESULTS AND DISCUSSION

4.1 Household demographic characteristics

The household survey conducted at the two sites, the gender composition of respondents revealed that, of the total respondents 91.6% (110) were male headed while only 8.4% (10) were female headed. From the total sample, almost 64% were found between the age of 20-59 years of age and 8.7% were 60 years and above. The mean age of the sampled household was 42 years while the minimum and maximum year of age was 20 and 65 respectively.

Table 3 Age and sex structure

HH head characteristics	Response	Number of respondents	Percentage (%)
Age	20-39	49	40.8%
	40-59	64	53.3%
	60 and above	7	5.9%
TOTAL		120	100%
SEX	Male	110	91.6%
	Female	10	8.4%
Total		120	100%

Source: House hold survey, 2019

4.1.1. Marital status and family size

The average family size of the individual households in the study area as a whole is 5.7. However, it ranges widely from 3 to 11. Majority of the sampled household heads have three to eight family members accounting for 106 households respectively from the total sampled 120 households. Respondents with less than three members constitute 6.7% whereas farmers with eight and more members share 5%. Some extremely large family sizes were observed in the survey with some of them having 9 – 11 family members.

Table 4 Marital status and family size of respondents

Characteristics	Status	Number of respondents	% age
Marital status	Single	-	-
	Married	113	94.1
	Divorced	-	-
	Widowed	7	5.9
	Total	120	100
Family size	Size of members	Total number	% age
	<3	8	6.7%
	3-5	72	60%
	6-8	34	28.3%
	>8	6	5%
	Total	120	100

Source: Field survey, 2019

Marital status is an important variable affecting fertility behavior since most of the births take place within marital union. So the change in the distribution of marital status has an important bearing on the size of households. The survey at the two sites has revealed that 94.1% of the sampled respondents were married while the rest 5.9% was widowed. As with the family size of respondents, the average household size in the study area stood at 5.7 members per households. The survey result also revealed that female population is slightly higher (51.3%) than male population (47.7%). The age structure is greatly dominated by young people of less than 15 years (45.1%) which is likely to result in continued rapid population growth. On the other hand, about 54.9% of the population is found in the working age groups of 15-64 years. This indicates that, as it is true for Ethiopia and some other developing countries especially in sub-Saharan Africa, the population is predominantly young, and this in turn indicates the existence of high fertility rate. Therefore, the implication is that there will be increased demand for crop land, expansion of coffee plantation, land for expansion of settlement, fuel wood and construction and other natural recourses. Such pressure on the forest resources inturn accelerates degradation and loss of natural forest.

4.1.2. Educational status

The data presented in Table 5 reveals that 34.2% of the respondents cannot read and write. The corresponding shares of respondents who have received primary education comprise

55% and only 10.8% of them attained secondary school education. This indicated that in regard to the attainment of education most respondents were not favored in terms of education.

Table 5 Education status of the respondent

Education status	Frequency	% age
Illiterate	41	34.2
1-4	43	35.8
5-8	23	19.2
9-12	12	10
Above	1	0.8
Total	120	100

Source: Field survey, 2019

Results on the highest educational level attained by *household* respondents revealed that 55% have primary level of education, while only 10% have attended their secondary level of education, respectively. The average education level of the respondent showed a negative relationship with forest product collection and extraction from the forest as increasing educational level made forest product collection increasingly unprofitable. This may be due to the fact that all labor time allocated for forest product collection is positively and significantly related to quantity of harvesting or collection. Therefore, the finding is similar to Mamo, *et al*. (2007), who concluded that educational level of the household is negatively related to forest dependency.

4.1.3. Land size and use

The land holding size of households in the sample is one of the limiting factors for better management of the existing natural forests and for additional planting of trees as buffer zones to minimize pressure on the natural forest. The survey result indicated that there is variation in land holding sizes among the various households and the land holding sizes can generally be classified in to four different classes as: < 0.5 ha, 0.5-1.0 ha, 1.01-2.0ha and >2.ha (Table 6).

Table 6. Distribution of Landholding Size (ha) of Household Heads

Land holding size	Frequency	%age
< 0.5 ha	46	38.3
0.5-1.0 ha	29	34.2
1.01-2.0 ha	38	31.7
>2.ha	7	5.8
Total	120	100

Source: Field survey, 2019

According to this report, over 72.5% of the respondents cultivate farmlands with areas less than 1.0 hectare each. The implication was that households' asset, land size, was found to influence forest dependency negatively. According to the study result, larger landholding size asset decreased the level of dependency on forest products especially timber products from the natural forest.

4.2 Woody Species Composition and Diversity

Species accumulations curve was drawn to determine the total sample size required for the assessment of woody species. The result showed that it levels after 28th plot for the natural forest and 25th for the semi-forest coffee (Figure 2). This implies that the total number of samples taken for this study were sufficient. species accumulation curve

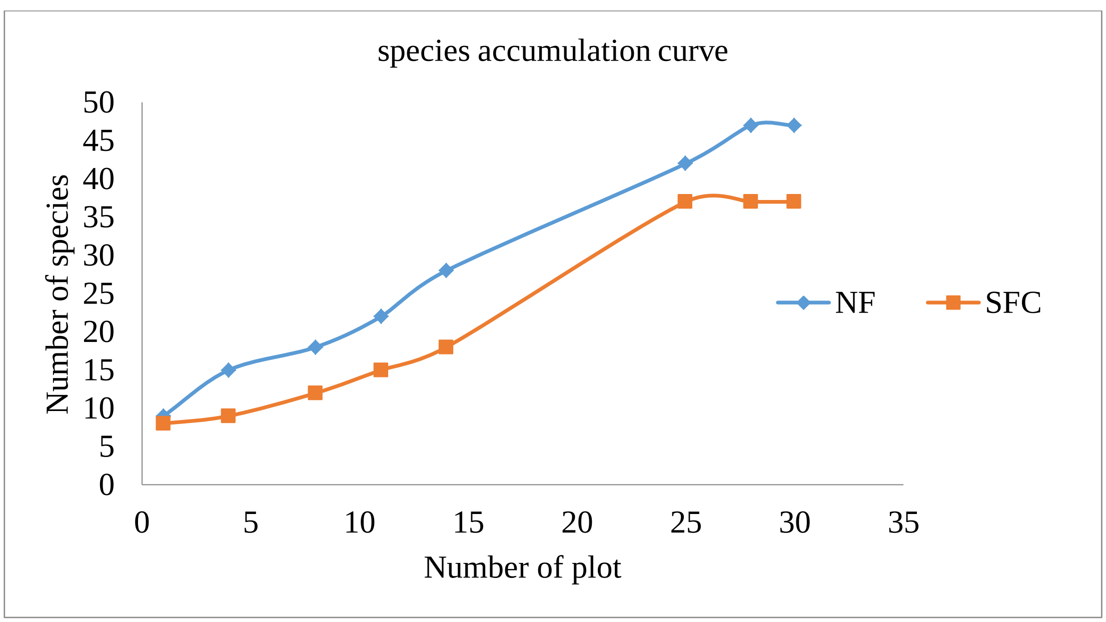


Figure 2.Species accumulation curve of natural forest (NF) and semi forest coffee (SFC)

A total of 66 species representing 43 families of woody species were recorded in all semi forest coffee and adjacent natural forest, of which 47 belonging to 26 families in natural forest and were 34 species belongs to 17 families in semi-forest coffee (Appendix 2 and 3). The most dominant families in natural forest were Fabaceae and Rutacea both contributing to 18% of the species recorded. Correspondingly, for semi forest coffee Fabaceae and Rutaceae family was the most diverse family having 14.8% and 14.8% of the species (Appendix 4). The family of Fabaceae and Rutaceae represented the majority of woody species in both natural forest and semi- forest coffee. 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). Dominance of Fabaceae reported from other vegetation studies in woodlands of Ethiopia due to adaptation potential of Fabaceae families to wider agro-ecologies (Teshome *et al*., 2004). The Sorensen's floristic similarity index showed that the natural forest and semi forest coffee share high woody species *(Ss*=42%). Twenty-nine woody species were common to both natural forest and semi forest coffee (Table 7). They had similarity in woody species composition between natural forest and semi forest coffee, which revealed that the woody species in the semi forest coffee are established from natural forest by intensifying management on woody species and they had the same species combination and remnants of the past forest. This finding is supported by Molla and Asfaw (2014), who shows that (58.67%) of woody species composition similarity existed between natural forest patches and enset based coffee agro forestry.

Table 7. Common woody species for both natural forest and semi-forest coffee

Scientific Name	Family
Albiziagummifera	*Fabaceae*
Albziagrandibracteata	*Maytenusundata*
Bersamaabyssinica	Melianthaceae
Clausenaanisata	Rutaceae
Cordia Africana Lam.	Boraginaceae
Croton macrostachyus	Euphorbiaceae
Crotolariamildbraedii	*Fabaceae*
Canthiumoligocarpum	*Rubiaceae*
Dracaena afromontana	Dracaenaceae
Diospyrosabyssinica	Ebenaceae
EhretiacymosaThonn.	Boraginaceae
Fagaropsisangolensis	Rutaceae
Ficussycomorus L	Moraceae
Ficusovata	Moraceae
Galineria saxifrage	Rubiaceae
Justiciaschemperiana	*Acantaceae*
Maytenusarbutifolia	Celasteraceae
Millettiaferruginea	Fabaceae
Mimusops kummel	*Sapotaceae*
Oleacapensis L.	Oleaceae
Oleawelwitschii	Oleaceae
Phoenix reclinata	Arecaceae
Phoenix reclinata	Arecaceae
Pouteriaadolfi-friederici	*Sapotaceae*
Polysciasfulva	Araliaceae
Sapiumellipticum	Euphorbiaceae
SpathodaCompanulata	Bignoniaceae
Schessleraabyssinica	Araliaceae
Syzygiumguineense	Myrtaceae

The woody species (individuals) recorded in natural forest were 58.12% (1038) trees and 33.76% (603) shrubs with few lianas 8.12% (145), whereas in semi forest coffee 64.2% (386) were tree, 35.8% (216) shrubs (Figure 3). The number of woody species varied considerably in the sites under consideration; the tree and lianas were high in natural forest than semi-forest coffee. The shrubs had some difference between natural forest and coffee agro forests. This variation is due to continuous clearing of the undergrowth vegetation for coffee management, which had caused reduction in woody species in the semi-forest coffee.

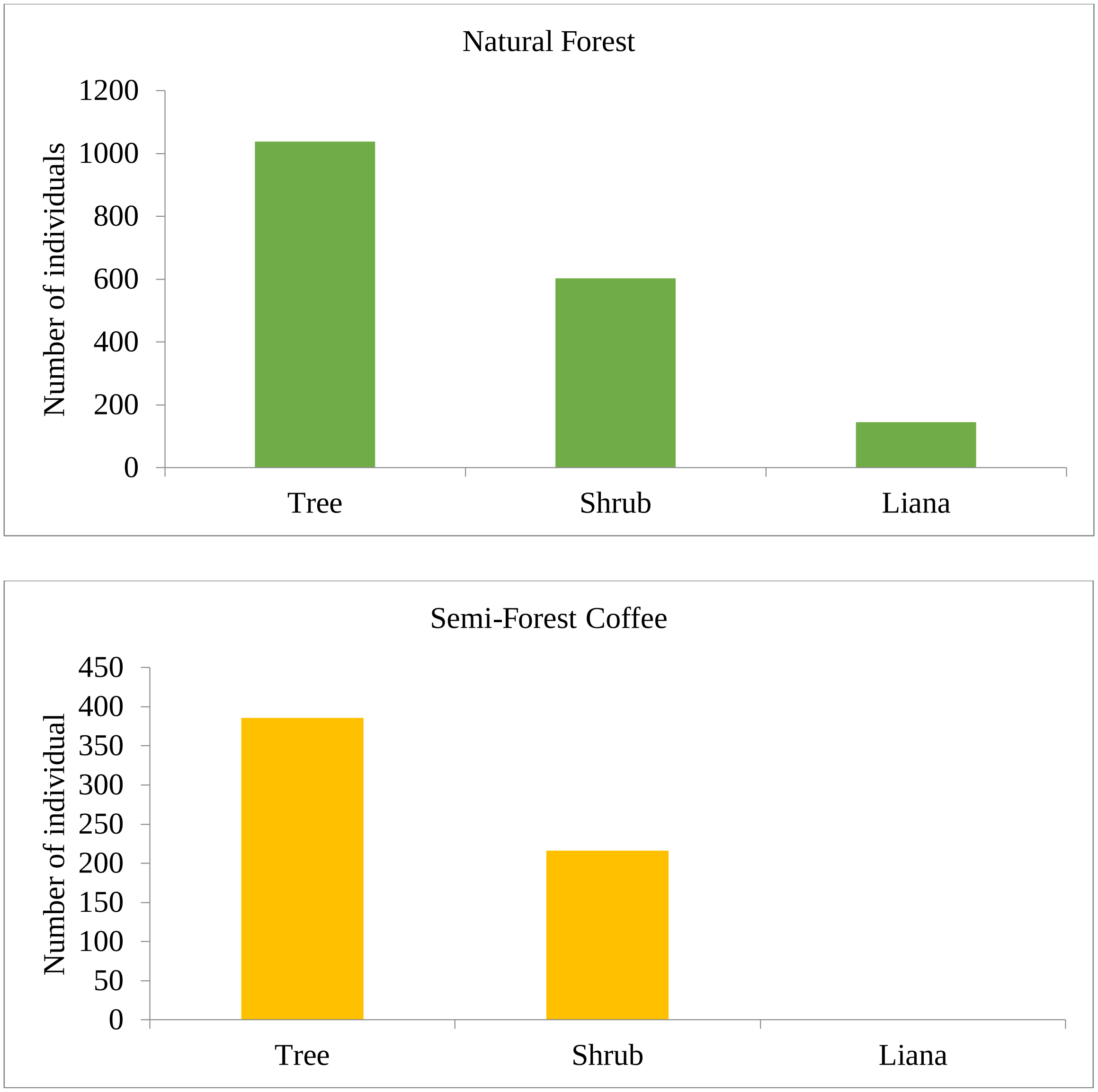


Figure 3. Growth habits of woody species in natural forest and semi forest coffee

4.2.1. Wood species diversity

In natural forest, 47 woody specie were recorded where as in semi-forest coffee only 34 different woody species were recorded (Appendix 4). Although the result shows more woody species under natural forest compared to semi-forest coffee, statistical not significant difference ($p > 0.05$).This study is supported by Molla and Asfaw (2014), who reported 43 different woody species were recorded in natural forest whereas 32 woody species were recorded in the enset based coffee agro forestry in the Midland of Sidama Zone in Ethiopia. Shannon‟s diversity index of woody species in natural forest (H‟ = 2.76) and semi-forest coffee with coffee (H'' = 2.69). However, the difference in Shannon diversity of woody species was not statistically significant difference ($p > 0.05$) between the natural forest and semi forest coffee (Table 8). This could be the uniform distribution of species in semi-forest coffee and enriched by the farmers with economically important species that meet the needs of the local people in semi forest coffees.

Table 8. Diversity of woody species in natural forest and semi-forest coffee

Forest site	**Richness**	**Diversity**	
		Shannon index	**Evenness**
Natural forest	47	2.76	0.79
Semi forest coffee	34	2.69	0.71
P-value	0.168	0.361	0.289

This study agrees with the study of Tadesse *et al*. (2014) which demonstrated higher Shannon diversity in natural forests than semi-forest coffee. The present study is also supported by Boakye *et al*. (2012) who reported that higher diversity index in Ghana natural forests than Taungya agro forests. According to Likassa (2014) higher species diversity in adjacent natural forests than shade coffee farms due to difference in the management practices so coffee farms generally characterized by selective retention of some over story trees. Shannon's evenness for natural forest and semi-forest coffee were 0.79 and 0.71 respectively. No differences were observed in evenness of species in both natural forests and semi-forest coffee. This study supported by Molla and Asfaw (2014) who reported that Shannon evenness of woody species was no significant difference observed between natural forest and enset based coffee agro forestry.

4.2.2. Importance value index

The IVI is an aggregate index that summarizes the dominance, abundance and frequency of a species. IVI of all woody species in the natural forest and semi-forest coffee were listed in Appendix 5 and 6. Accordingly, the ten leading dominant and ecologically important woody species in natural forest and semi forest coffee were given in ascending order in Table 9. The species with the highest IVI were *Olea capensis* (57.17%), *Tecleanobils* (30.58%), *and Croton macrostachyus* (21.49%) followed by other species in natural forest. Whereas in semi-forest coffee, highest IVIs were *Schefflera abyssinica* (27.04%), *Sapium ellipticum* (27.01%) and *Vepris dainelli* (26.96%) 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 (Worku *et al*., 2012).

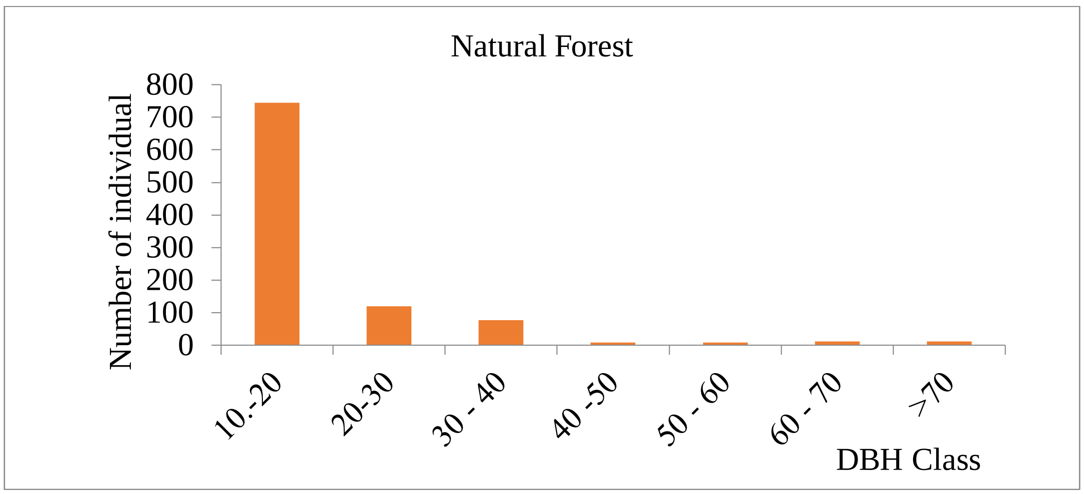
Table 9.Importance value index of woody species in natural forest and semi forest coffee

Natural forest		**Semi forest coffee**	
Botanical name	**IVI**	**Botanical name**	**IVI**
Oleacapensis L.	57.17	*Scheffleraabyssinica*	27.04
Tecleanobilis	30.58	*Sapiumellipticum*	27.01
Croton macrostachyus	21.49	*Veprisdainelli*	26.96
Crotolariamildbraedii	13.83	*Bersamaabyssinica*	22.68
Millettiaferruginea	12.31	*Syzygiumguineense*	19.67
Dracaena afromontana	11.45	*Diospyrosabyssinica*	18.83
Canthiumoligocarpum	11.05	*Croton macrostachyus*	18.53
Bersamaabyssinica	10.09	*Millettiaferruginea*	16.89
Diospyrosabyssinica	9.84	*Oleacapensis*	16.69
Ehretiacymosa	8.53	*Albiziagummifera*	15.96

Those species that have been identified to have high IVI value were mainly due to their high dominance. 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. The IVI values are used in conservation programs, where species with low IVI values are prioritized for conservation (Shibru and Balcha, 2004) and those with high IVI values need monitoring management (Gurmessa *et al.*, 2012).

4.2.3. Population structure

Distribution of all individuals in different DBH size classes in the natural forest and coffee agro forests showed more or less inverted J-shape, there were greater numbers of individuals in the lower diameter size class. In natural forest, 55.66% and semi forest coffee 54.92 % of individuals were concentrated in the first lower diameter size class. Only 0.59% in natural forest and 2.89% in semi forest coffee 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.



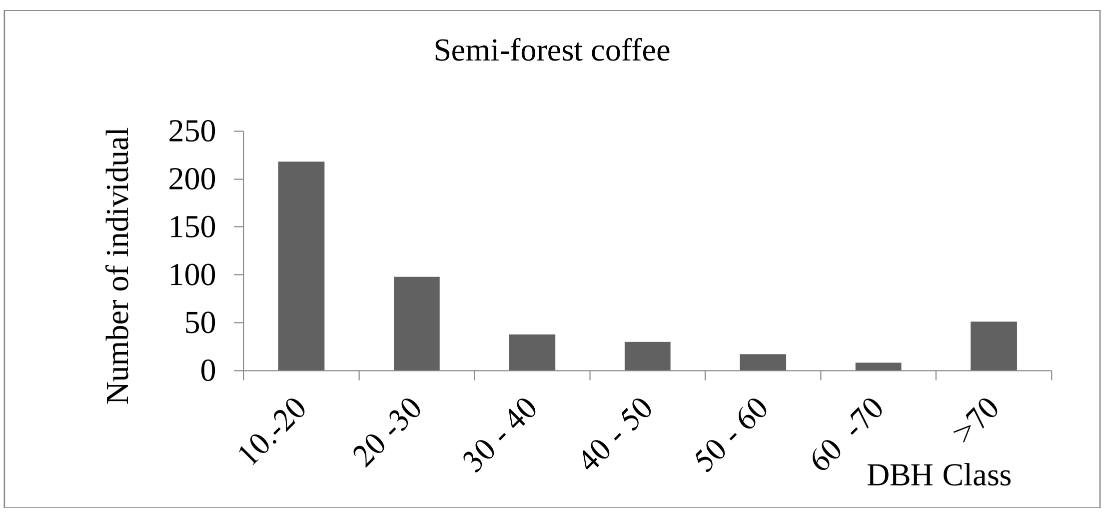
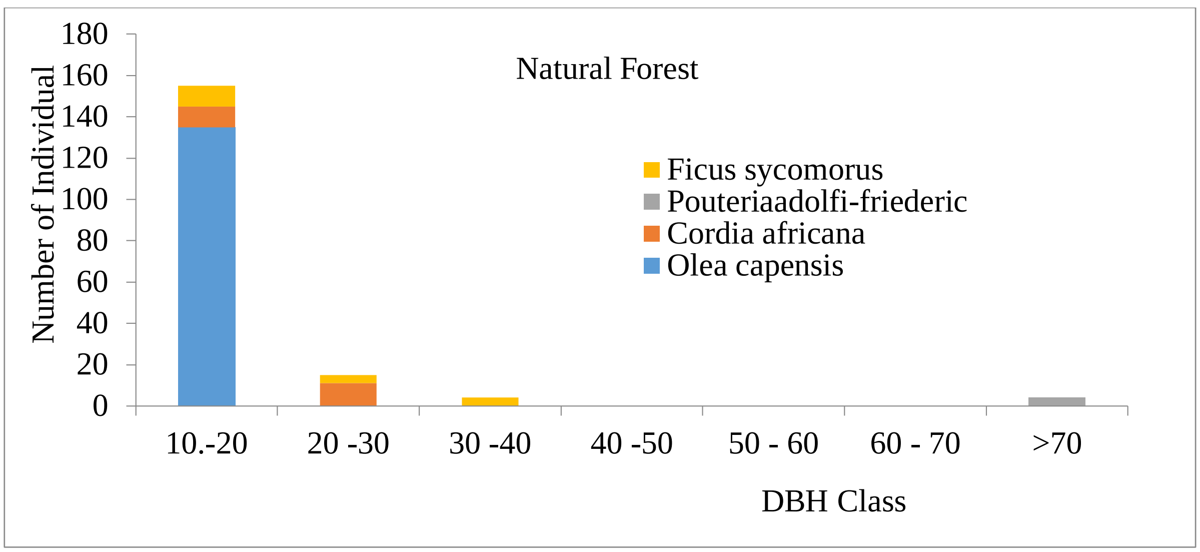


Figure 4 Diameter class distributions of woody species in natural forest and semi forest coffee.

Some of woody species density distribution of diameter classes of woody species resulted in different patterns in both natural forest and semi forest coffee (Figure 4). The highest DBH of trees in natural forest >100 cm was contributed by *Olea welwitschii* (286cm), *Pouteriaadolfi-friederici*(241cm), *Schefflera abyssinica*(209.55cm) *and Ficus vasta* (123.88cm) and in semi forest coffee highest DBH >100 cm were recorded by *Olea welwitschii* (168cm), *Sapium ellipticum* (124cm) and *Schefflerra abyssinica* (102cm) species. The overall structure of the natural forests and semi forest coffee 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 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 woody species in forest by the local people both for domestic consumption and for generating income.



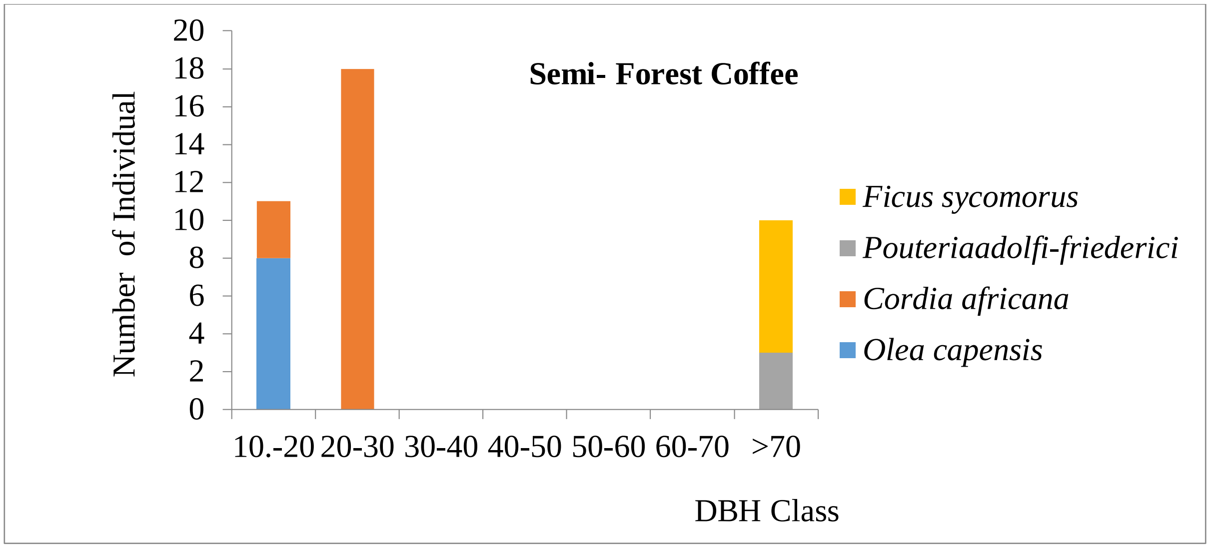


Figure 5 Diameter class distribution of some selected species in Natural forest and Semi forest coffee

Diameter at Breast Height distribution of some selected species in natural forest and semi-forest coffee shows highest frequency distribution in the lower diameter classes and a gradual decrease towards the higher classes. For example when we see *Olea capensis* and *Cordia Africana* the density of individuals in the lower DBH class is very high both in natural forest and semi forest coffee but no individual in medium and higher DBH classes. This showed that there is selective cutting of the species for different purposes like for construction, farm tools, furniture making and fuel wood. *Ficus sycomorus* and *Pouteria adolfi-friederici* shows a type of frequency distribution in which there is a low number of individuals in the lower diameter classes but increases towards the higher classes for *Ficus sycomorus* in natural forest but *Pouteriaadolfi-friederici* only found in the higher diameter class in both natural forest and semi forest coffee. And both species has no individual in medium diameter class in both forests (Figure 5). The only difference between natural forest and semi forest coffee is in number of individuals of each species.

4.2.4. Regeneration status

The present study showed that the natural forests had higher density of seedling and sapling than semi forest coffee. The mean density (number of individuals ha-1) of seedlings and sapling of the woody species showed significant ($P < 0.05$) differences between natural forest and semi forest coffee (Table 10). This indicated that natural forests have higher regeneration status than semi forest coffee. However, the mean density of tree in natural forest and semi forest coffee shows no statistically significant difference ($p > 0.05$). When the natural forests are converted in to semi forest coffee 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 trees 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 semi forest coffee. This study is supported by Tadesse *et al*. (2014) who reported that natural forest fragments have higher regeneration and recruitment than the semi-forest 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 of species regeneration.

Table 10. Density of seedling, sapling and tree of natural forest and semi-forest coffee

Growth stage	Natural forest	Semi forest coffee	P–value
	Density ha-1	Density ha-1	
seedling	1834.14	1346.7	0.026
sapling	575.52	422.9	0.023
Tree	456.12	423.3	0.106

4.3. Woody species uses and conservation

4.3.1. Woody species uses diversity

Woody species use categories were recognized plants for medicine, food (edible), honey, material sources (including lumber, beehives), social services (ritual/religious value) animal fodder and environmental uses (shade for coffee, live fences, etc.) (Table 11).The number of species for each use category is indicated in table 11.

Table 11. Woody species recorded and use categories in natural forest and semi-forest coffee

No	Scientific name	Vernacular name	Habits	Parts used	Type of usages	Sites NF	Sites SFC
1	*Acantaceae*						
	Justicia schemperiana	Dhummuugaa	S	Root	Medicinal value	*	*
2	*Araliaceae*						
	Schefflera abyssinica	Bottoo/gatamaa	T	Flower and wood	For honey production and house material	*	*
	Polyscias fulva	Kariyo	T	Flower and timber	For honey production and timber	*	*
3	*Arecaceae*						
	Phoenix reclinata	Meexii	T	Fruit seed and leaf part	Fruit edible and the leaf for basket making	*	
4	*Aspleniaceae*						
	Asplenium protensum	Qawoo/ Gawoo	L		For fencing and for bee hive	*	
5	*Anacardiaceae*						
	Rhus glutinosa	Xaxesa	S/T	Wood part	Fuel wood	*	*
6	*Apocynaceae*						
	Landolphia buchananni	Yebo	L	Wood	Fencing and for bee hive	*	
7	*Boraginaceae*						
	Ehretia cymosa	Ulaagaa	T	Leaves and stem	Leaves for medicinal value and stem for farm tool	*	*
	Cordiaafricana Lam.	Waddeessa	T	Fruit ,flower and stem	Fruit edible ,flower for honey be flora and stem for furniture making, house door and window (construction)		
	Spathoda Compamulata	Anunmuu	T	Leaves	Leaves for medicine and	*	*

				and stem	stem for construction		
8	*Combretaceae*						
	Combretum paniculatum	Baggee	L	Stem ,flower and leave	Flower for honey bee flora stem and leave for medicinal value	*	
9	*Celastraceae*						
	Maytenus gracilipes	Kombolcha	S	Stem	For fencing and house construction	*	*
	Hippocrata africana	Xiyoo	L	Flower and stem	Honey bee flora and stem for bee hive	*	
10	*Dracaenaceae*						
	Dracaena afromontana	Emoo	S		For fencing ,fodder for animal and bee hive	*	
11	*Ebenaceae*						
	Diospyorus abyssinica	Lookoo	T	Stem	To put bee hive on it and house construction	*	*
12	*Euphorbiaceae*						
	Croton macrostachyus	Makkanniisa	T	Leave ,flower and stem	Leave for medicinal value, flower for honey bee flora and stem for construction	*	*
	Sapium ellipticum	Bosoqa	T	Stem and leave	Fuel wood and fodder		
13	*Fabaceae*						
	Crotolaria mildbraedii	Yubdo	T	Leave and stem	For fencing and fodder for animal	*	*
	Albizia gummifera	Hambabbeessa	T	Stem	Shade for coffee and house construction		*
	Milletia ferruginea	Askira	T	Stem	For charcoal ,fuel wood and shade for coffee		*
14	*Melianthaceae*						
	Bersema abyssinica	Lolchiisaa	T	Stem	Fuel wood and charcoal production	*	*
	Ekebergia capensis	sombo	T	Stem	Timber, to put on it bee hive and social value(mootii bosonaa)	*	
15	*Maytenusundata*						
	Albzia grandibracteata	Halele	T	Stem	Fuel wood	*	*
16	*Menispermaceae*						
	Tiliacora troupinii	Liqixii	L	wood	For fencing	*	
17	*Moraceae*						
	Ficus sycomorus	Harbuu	T	Stem and fruit	Stem to make bee hive and to put on it ,fruit fodder for animal	*	*
	Ficus ovata	Dembii	T				
	Ficus vasta	Qilxuu	T	Stem	To put bee hive on it and	*	*

					as shade for coffee		
18	*Myrtaceae*						
	Syzygium guineense	Baddeessaa	T	Fruit and stem	Fruit edible and wood for timber of house construction	*	*
19	*Oleaceae*						
	Olea welwitschii	Bayaa	T	Stem and bark	Stem to put bee hive on it and for beehive attractive smell	*	*
	Chionanthus mildbreadii	Gajaa	T	Stem	For house construction and use for farm tools	*	*
20	*Pittosporaceae*						
	Pittosporum viridiflorum	Soolee	T	Bark ,leave and stem	Bark and leave for medicinal value, stem for fuel wood	*	*
21	*Rutaceae*						
	Clausena anisata	Ulumaaye	S	Stem	Farm tools and for clearing tease	*	*
	Tecleanobilis	Mixirii	T	Stem	Farm tools and house construction	*	*
	Vepris dainelli	Hadheessa	T	Stem	Farm tools		
22	*Rubiaceae*						
	Galinieria saxifraga	Simararum	T	Stem	Fuel wood and fencing		
	Canthium oligocarpum	Miixoo	T	Stem	For storage construction and fencing	*	*
	Oxyanthus speciosus	Embirango Jaldesa	H	Stem	construction	*	
23	*Sapotaceae*						
	Mimusops kummel	Kolaatii	T	Stem	House construction and timber	*	
24	*Sapindaceae*						
	Allophylus abyssinicus	Se'o	T	Stem	Fuel wood and house construction	*	*
	Pouteriaadolfi-friederici	Qararo	T	Stem	House construction, timber and for furniture	*	*
25	*Tiliaceae*						
	Grewie ferruginea	Burumii	T	Stem	For farm tool, construction of house and fencing	*	

4.3.2. Woody species use for honeybee flora

Across the study areas, 11woody species representing 9 families were recorded as being sources of honeybee forage in the natural forest where 9 woody species representing 7 families in semi- forest coffee. As the majority of honey production in the study areas is more of traditional type, these species are highly important in both natural forest and semi forest coffee. There are no differences in both natural and semi-forest coffee.

4.3.3 Woody species used as source of food

In the study area 5 woody species belonging to 5 plant families were considered by the local people as edible in natural forest and 4 woody species belonging to 4 families in semi-forest coffee. Boraginaceae, Moraceae, Myrtaceea ,Arecaceae and Apocynaceae families each representing by one species in natural forest and the same for semi forest coffee and the only difference is the absence of Apocynaceae family in the semi forest coffee. The majority of the recorded edible species have their fruits and/or seeds as the edible parts. Generally, fruits/ seeds tend to be more common. The edible woody species were recorded in natural and semi-forest coffee has almost similar.

4.3.4 Woody species used as medicine

A total of 5woody species belonging to 5 families were recorded as having medicinal uses in natural forest and the same to semi-forest coffee (Table 11). These species are used to treat various kinds of ailments of humans and livestock such as rabies, viral disease, headache, stomachache, wounds, etc. (Table 11). A comparison of the households' wealth category revealed that the poor household (95%) uses the highest number of woody species for the treatment of different illnesses followed by medium (62%) households. However, some species are well known across all households for their medicinal values, e.g., *Fagaropsis angolensis* and *Croton macrostachyus.*

4.3.5 Woody species used as animal fodder

In two studied site, many grass and herbaceous species are usually used for animal fodder. However, this study considered only shrubby, liana and tree species that are known to be fodder plants. Overall, five species were cited as important sources of animal fodder in the study area both in natural forest and semi-forest coffee. Some of these species were used by all household wealth categories and include *Crotolaria mildbraedii, Dracaena afromontana*. *Ficus vasta*, *Ficus sycomorus* L. and *Sapium ellipticum.*

4.3.6 Woody species use for farm tools and domestic uses

Over 30 and 27woody species in natural forest and semi forest coffee were respectively as being used to make different house utensils, farm tools, lumber and baskets. Among these Cordia *africana*, *Landolphia buchanonni*, *Ekebergia capensis*, *Ficus vasta, Phoenix reclinata*, and *Pouteria adolfi-friederici* are mostly used woody species. In this regard, the highest numbers of woody species were recorded in natural forest (30). For example, *Phoenix reclinata* leaves are used to make baskets, used as mats for floor covering, containers to carry goods or basket-like, general-purpose containers. The products are highly marketable and can be found in many local markets. *Landolphia buchanonni* widely used as special rope that can be used locally and also marketed in some places. Many of the other available tree species are used as building materials in carpentry, woodwork, furniture and utensils. The majority of tools and household items are made up of woods from the different tree species. Some species are used for food and for fencing purposes. Some other species such as *Teclea nobilis, Canthium oligocarpum, Ehretia cymosa* and *Grewie ferruginea are* woody species used for farm tool from a natural forest.

According to all respondents both coffee and honey are important sources of livelihoods in the area. Also fuel wood and charcoal are important sources of livelihoods for poor households in both natural forest and semi- forest coffee area. Other like fruits and seeds of wild edible woody species and medicinal values are less traded and mostly used for home consumption as highlighted by respondents. However, the woody species in natural forest and semi-forest coffee are offering various goods and services for the local communities living in and around them. Despite their importance, however, the forests and their products are less managed in natural forest and semi forest coffee areas. Many people perceived the resources as communal or open access anybody could go and collect whenever there is an opportunity especially in natural forest. If the potential of woody species resources is to be managed and sustainably used by local communities, then ownership of the resources must be clearly established. There is little incentive for the local communities to engage in management activities as land tenure is uncertain (Agrawal, 2003, Fisher *et al.* 2010). Many rural households, especially those with little land of their own, rely on common property areas for gathering wild plants or woody products that contribute to their household economies.

4.4. Forest product uses and access

The livelihood of households in the study area was largely depends on timber and non-timber forest products. However diverse forest products were collected by households for home consumption and for sale and most of the products were obtained from this forest. The major forest products reported by households include firewood, honey, construction wood/timber, charcoal and medicinal plants. The dependence of households on timber and non-timber forest products in the case of natural forest, 15.2% of the household respondents explained that they access uses of timber in the natural forest area restricted. Where, about 84.8% household respondents responded that access to use timber in natural forest is without any restriction. In contrast, in the semi forest coffee all of the respondents report that access to use timbers highly restricted. Because the semi forest coffee was managed and protected by the owner and no one can enter and use the timber where as in natural forest it is open access everyone was using the timber products. In addition, the household respondents of semi-forest coffee can get dead branches or wood from their own farms for their fuel wood and lumber needs. Most households (rich and medium who have large land holding size) look forward to harvesting NTFPs and timber from their owned land and a considerable increase in their cash income from semi-forest coffee and those poor farmers are more depend on the natural forest. Therefore, the household of semi-forest coffee decrease their dependence from the natural forests.

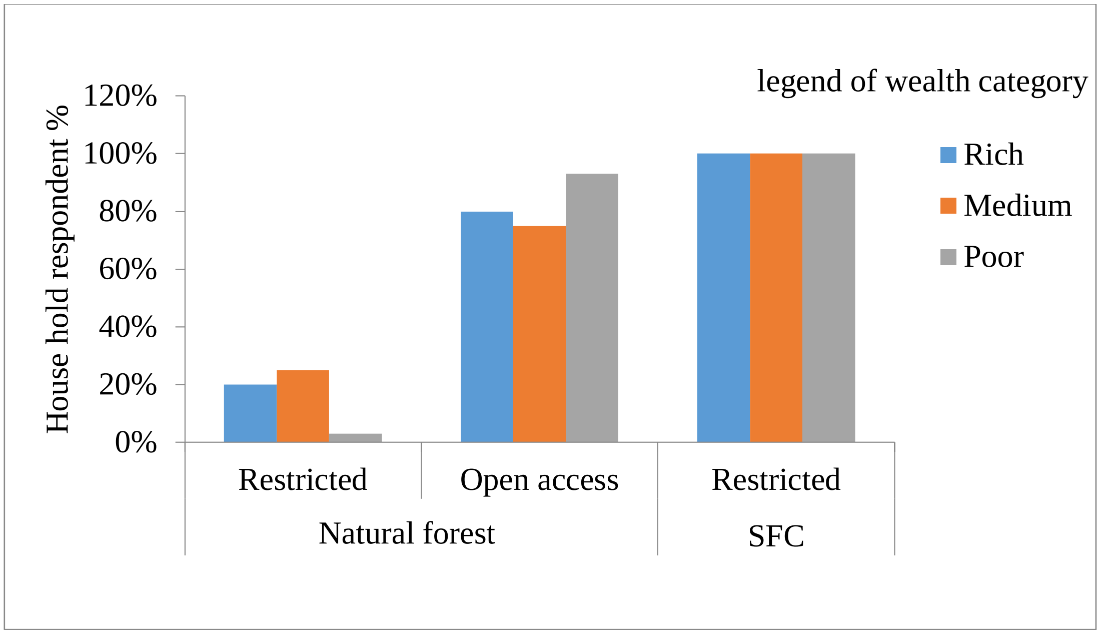


Figure 6 Access of timber in natural forest and semi forest coffee

In the natural forest, 92.1% of the three wealth category (rich, medium and poor)household respondents use the NTFPs as common from the forest where as 7.9% household respondents revealed that collection of different NTFPs restricted in natural forest. The majority of respondent uses NTFPs from forest of their livelihood such as lianas, fuel wood, medicinal plants, farm tools, fodder, construction purposes and spice support there live. Yet, in semi-forest coffee, access to use NTFPs high restricted around 87.7% of household respondents reported that no one could use NTFPs in the area because of their property (Figure 7). However, 12.3% of the household respondents stated that they have access to collect NTFPs in semi- forest coffee. They were allowed to collect some of NTFPs products such as fuel wood and medicinal plants after the coffee harvested. Accordingly, semi-forest coffee under the ownership of farmers have existed so far mainly because of the way they have been cultivating coffee with a management for the most he time restricted because clearing of undergrowth before collection of coffee berries.

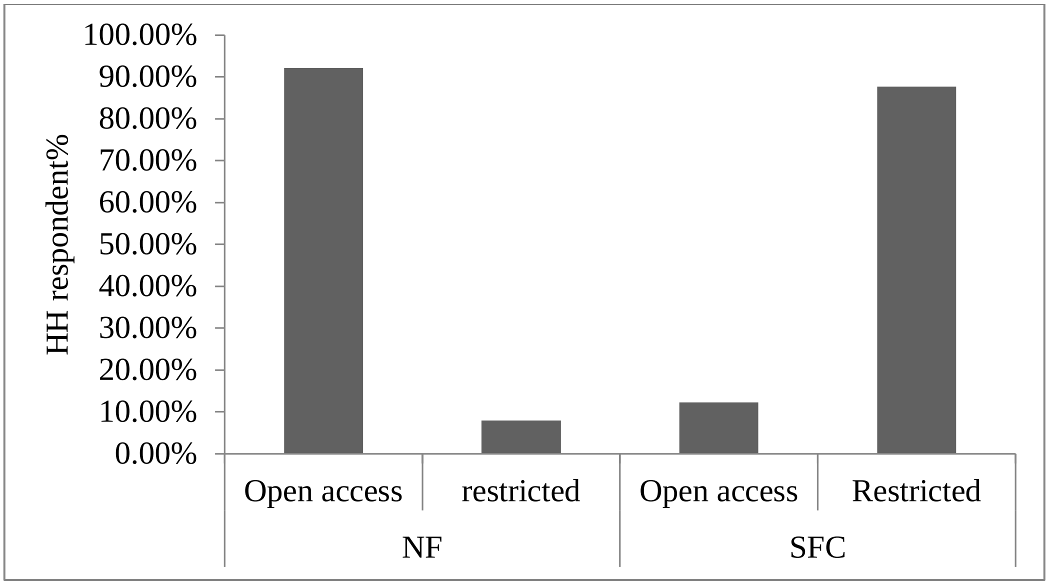


Figure 7 Access of NTFPs in natural forest and semi forest coffee

Forest resources in the natural forest are accessible to any community member thereby leading to the forest resource being open to extraction to anyone. Generally, most households in the natural forest depend on accessing forest resources for their day-to-day use. 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).

4.4.1. Status of forest area

The result of the study revealed that 69.7%, 68.2 and 64.5 of the rich, medium and poor respondents perceived the existing natural forest as decreasing, where as 28.3%, 28.4 and 32.5 of the respondents perceived as no change. However, 2%, 3.4% and 3% rich, medium and poor household respondents said forest areas increasing (Figure 8).

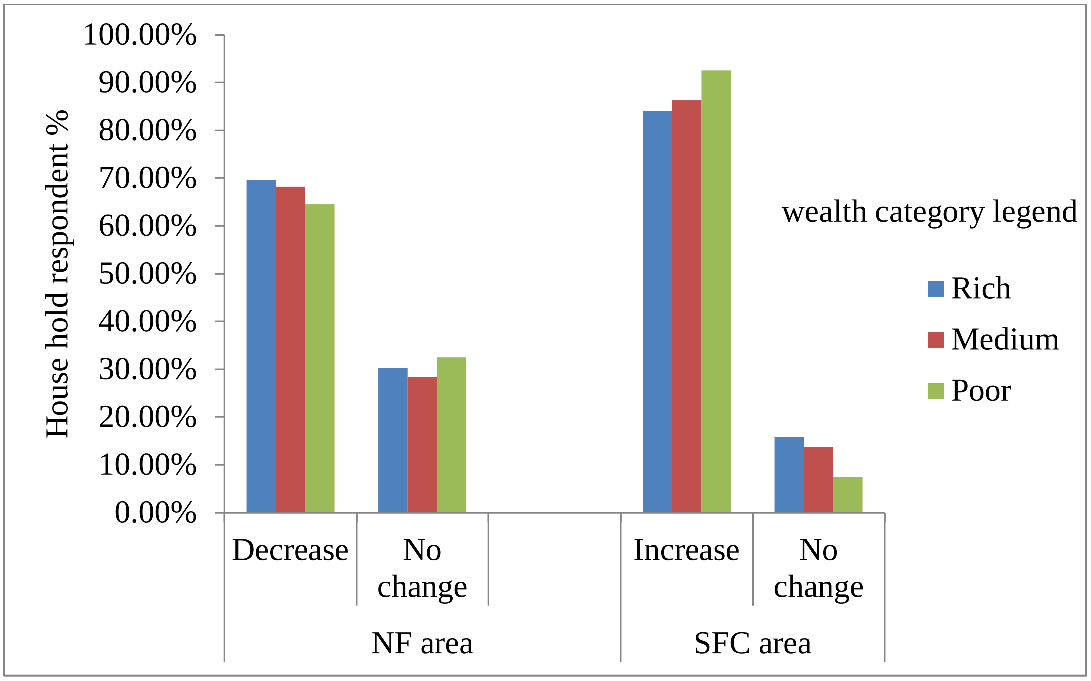


Figure 8 Status of forest area in natural forest and semi forest coffee

In the semi forest coffee 84.1%, 86.3% and 92.5% of the rich, medium and poor respondents, stated that were forest area are increased. Whereas 15.9%, 13.7% and 7.5% of the respondents responded that forest area was no change. The main reasons of semi-forest coffee area are increasing were expansions of coffee plantation. In general, the forest area were gradually depleted and destroyed due to increased extraction of timber and non-timber forest products, and converted into agricultural land. However, decreases in forest area coverage in the study area were indicated as indicators of decrease in functions and services of forests. This study agrees with Melaku *et al*. (2014) who reported that about 84% of the respondents stated that the forest cover of the area was decreasing, while 13% reported that no change. According to the respondents, the main causes of forest degradation in the study area were expansion of agricultural land, fuel wood collection, charcoal making, land use change by investors and settlements of people. The present study is in agreement with by Tadesse *et al*. (2013) who reported that the majority (95%) of interviewed households reported decreased forests lands. A few respondents (5%) described increase in forests lands. The present study also agree with the study conducted in Harena coffee forest experiencing serious human pressure, mainly through agricultural expansion, settlements and conversion of the undisturbed forest in the intensively managed coffee forest (Woldemariam and Senbeta, 2008). However, as in other of the country, the forest areas in this region are declining rapidly, primarily due to the conversion of forests into agricultural land (Bekele, 2003).

4.4.2. Status of woody species composition

Response from rich, medium and poor household respondents in average revealed that 68.4% and 82.6 % of the respondents tells as the woody species composition of natural forest and semi forest coffee highly decreasing. Whereas 12.9% and 7.4% respondents reported that species compositions of natural forest and semi-forest coffee were increasing (Figure 9). However about 18.7% of the respondents stated that the species composition of natural forest were no change in woody species composition. The main reason of species composition is decreasing in the study area were cutting tree for farm tools, construction purposes, for coffee management, fuel wood collection, timber and improper use of fire for beekeeping.

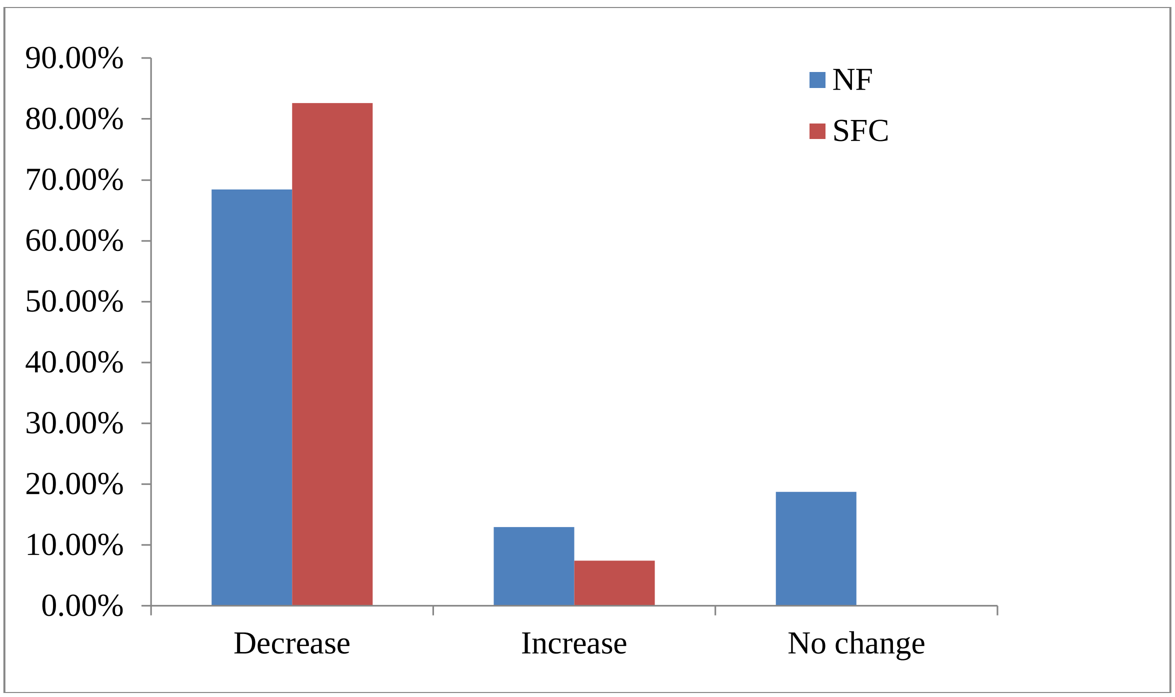


Figure 9 Status of woody species composition in natural forest and semi- forest coffee

The contribution of coffee management to decreasing of species composition was through traditional management practices. Other using different tree species for construction purpose and timber production was reduces species composition. Likewise, livestock grazing in the forest cause damage of regeneration and ground vegetation. During the honey collection from the forest, poorly managed fire destroyed vegetation.

In both natural forest and semi-forest coffee, the household respondents were highly dependent on the forests and its biodiversity for their livelihoods, using a range of forest resources, mainly NTFPs, for household consumption and income generation.

This study supported with the a study in India by Shekhar (2001) who reported that harvesting of fuel wood and timber has profound effects on the biodiversity of the forest ecosystem, often leading to the change in species composition and vegetation structure. The author also noted that the uncontrolled grazing by domestic livestock is another aspect of removal of biomass from natural ecosystems, which has direct impact on the regeneration process of forest by removing the young saplings and soil loss due to trampling. The rapid conversion of tropical forests for agriculture, timber production and other uses has generated vast, human-dominated landscapes with potentially direct consequences for tropical biodiversity loss (Gibson *et al*., 2011). Forest conversion, agricultural expansion, and infrastructure extension have transformed landscapes, resulting in biodiversity loss and threatened ecosystem services (Geist and Lambin, 2002).

4.5. Soil organic carbon

Bulk density, texture and pH

There were no significant differences ($P>0.05$) in bulk density across the two land use types and elevations. The difference in pH was marginally significant between land use systems. The semi forest coffee had the highest pH values. However, all the pH value fall under acidic soil which may result due to high rainfall is recorded every year in the area. The soil textures under land uses within each elevation were similar (Table 12) indicating the comparability of the site with respect to the soil.

Table 12 Mean values of Soil pH, bulk density, texture and SOC across the land use type

Parameters	Elevation	Land use		P-value
		Natural forest	Semi forest coffee	
PH (H2O)	1877-1890	5.78±0.56	6.14±0.68	0.016
BD(g/cm3	1877-1890	0.92 ±0.02	0.82±0.02	0.496
SOC%	1877-1890	51.35±0.11	50.64±0.08	0.828
Textural class	1877-1890	Sandy loam Loam	Sandy loam Loam	

Soil organic carbon

SOC at 0-30cm soil depth within the two land use types is shown in Table 12. SOC% in native forest and semi forest coffee were 51.35±0.11and 50.64±0.08 respectively. Native forest and semi forest coffee had no significant difference by its SOC. In the present study, the SOC loss from the conversion of native forest to semi-forest coffee remained very low.

The SOC depends on the balance between the annual input of dead plant material and the annual loss of SOC by decomposition (Nabuurs *et al,* 1997, Mulugeta, 2004, McDonagh *et al*., 2001, Bangroo *et al.,* 2011). In most terrestrial ecosystems, the majority of net primary production is shed in the form of plant litter, which originates from above- and below-ground plant organs (Swift *et al.,* 1979). Tree species differ in their allocation of C to above and below ground components and in their fine root mortality (Cairns *et al*., 1997). There is also a considerable site-specific variation in the quality and quantity of litter produced by different tree species (Aerts, 1997). These factors may explain the similar amounts of SOC in semi forest coffee as in native forest. And it may also suggest that the coffee based agroforestry system protects the loss of SOC, and if the annual agriculture reverts to coffee-based agroforestry in the study area, it could lead to SOC sequestration.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The woody species resource in both natural forest and semi-forest coffee is shown to be an important constituent of the natural capital available to the local people. The local community interaction in the natural forest and semi-forest coffee resource is dependent on various demographic and institutional factors such as family size, farm size, wealth/assets, tenure right and others which in turn are affecting local people usage of natural forest and semi forest coffee area resources. The study results illustrate that a total of 66 woody species representing 43 families are identified; 47 woody species from natural forest and 34 from semi-forest coffee respectively. A very small number of species represented most of the families. The two forests had showed differences in the species number and total stem count per hectare.

The description of population structure of woody species in natural forest and semi-forest coffee revealed inverted J-shaped graph that referred existence of more population from the lower age group and the existence of good recruitment potentials but having poorly represented in the intermediate diameter classes may be due to selective removal of medium sized individuals. The composition, distribution and density of seedlings and saplings are indicators of the future regeneration status of any forest. Hence, natural forest had larger density of seedling and sapling, but semi-forest coffee had more stem density at maturity stage. This variation may indicate anthropogenic disturbance that diminishes species at seedling stage.

Woody species contributes an important role in the livelihood of household heads in both forests. Fuel wood, honey, forest coffee, construction materials, medicine, farm tools and charcoal were major forest product sources. Woody species management practices in the study area of semi-forest coffee farms more or less the same to the adjacent natural forest. It was observed that woody species diversity and household dependency on coffee production increased with the closeness of the adjacent natural forest it was concluded that semi- forest coffee production system is an important land use system in minimizing the loss of woody species. The SOC loss from the conversion of native forest to coffee-based agroforestry remained very low. But despite the ongoing habitat conversion, the present study highlighted the presence of diverse woody species and their uses in some of the semi-forest coffee and natural forest, households live in the forest and the surrounding community is easily accessible for the forest product and coffee plantation. This is disturbing and reducing the size of the natural forest (causes forest degradation).

5.2 Recommendation

Regarding the importance of semi-forest coffee forest the same to the natural forest for biodiversity conservation and local livelihood as well as for sustainable use of forest resources and in soil organic carbon sequestration, the following points can be recommended in designing and implementing management strategies for this resource:

- Demarcation should be done between the semi-forest coffee and natural forest to manage over expansion of coffee plantation to the natural forest area with continuous monitoring of the forest area.

- Awareness should be generated among the local communities to adopt the strategy for the sustainable use of important species, such as *Ekebergia capensis, Ficus thonningii and Ficus vasta* who's rarely present in the study area and those woody species mostly used their timber products and who doesn't have regeneration like *Cordia Africana* and *Pouteriaadolfi-friederici*.

- All stakeholders which have a responsibility on the conservation of the forests had working on the substitution of woody species that doesn't have regeneration before they lost.
- And it may also suggest that the semi-forest coffee system protects the loss of SOC, and if the annual agriculture reverts to coffee-based agroforestry in the study area, it could lead to SOC sequestration.

5. REFERENCES

Abazinab M., Debele K. and Worku Z., 2017. 'Honey Harvesting, Utilization and Marketing inShabeSombo and Seka Chekorsa**Districts of Jimma Zone, Southwestern, Ethiopia**

Department of Animal Sciences, College of Agriculture', *Advances in Biological Research*, 11(3), pp. 132–138.

Ambinakudige S, Sathish BN, 2009.Comparing tree diversity and composition in coffee farms and sacred forests in the Western Ghats of India. Biodiversity. Conserve. 18:987-1000.

Albrecht, A., Kandji, S.T., (2003). Carbon sequestration in tropical agro forestry systems. Agriculture Ecosystem and Environment, 99, 15–27.

Baldock, J, Skjemstad, J & Bolger, T, (2007).Managing the carbon cycle‟ In Garden, D., Dove, H.and Bolger, T. (eds.) Pasture systems: managing for a variable climate. Proceedings of the 22nd Annual Conference of the Grasslands Society of NSW Queanbeyan, Grassland Society of NSW, 5-9.

Batjes, N.H. and Sombroek, W.G., (1997).Possibilities for carbon sequestration in tropical and subtropical soils. Global Change Biology, 3, 161–173.

Bangroo, S. A., Kirmani, N.A, Tahir, A., Mushtaq, A.W, Bhat, M.A and Bhat, M.I, (2011). Adapting Agriculture for Enhancing Eco-efficiency through Soil Carbon Sequestration in Agro-ecosystem. Research Journal of Agricultural Sciences, 2, 164-169.

Bekele, L., (2006). Impact of exotic tree plantations on carbon and nutrient dynamics in abandoned farmland soils of southwestern Ethiopia, PhD dissertation, Swedish University of Agricultural Sciences, Uppsala.

Bekessy, S. A., Wintle, B. A., Lindenmayer, D. B., McCarthy, M. A., Colyvan, M., Burgman, M. A. &Possingham, H. P. (2010). The biodiversity bank cannot be a lending bank. *Conservation Letters,* 3(3)**,** 151-158.

Bajigo, A. and Tadesse, M. 2015. Woody Species Diversity of Traditional Agro forestry Practices in Gununo Watershed in Wolayitta Zone, Ethiopia. *Forest Research: Open Access*.

BikilaMengistu and Zebene Asfaw, 2016. Woody species diversity and structure of agro foretery and adjacent land use in dellomena district, south east Ethiopia.

Boakye, E. A., Gils, H., Osei, E. M., and Asare, V. N. 2012. Does forest restoration using taungya foster tree species diversity? The case of Afram Headwaters Forest Reserve in Ghana. *African Journal of Ecology,* **50(3)**: 319-325.

Chapman, C.A., Chapman, L.J., Zanne, A. & Burgess, M.A., 2002. Does weeding promote regeneration of an indigenous tree community in felled pine plantations in Uganda? Restor. Ecol. 10, 408–415.

Correia M, Diabaté M, Béavogui P, Guilavogui K, LamandaN,DeForesta H. 2010. Conserving forest tree diversity in GuinéeForestière (Guinea, West Africa): the role of coffee base dagro forests.BiodiversConserv. 19:1725–1747. Doi: 10.1007/s10531-010-9800-6

CSA (Central Statistical Agency), 2014.Addis Ababa, Ethiopia and Population Census Commission, 2010, Population and housing census of Survey volume V, Ethiopia.

Dawson IK, Guariguata MR, Loo J, Weber JC, Lengkeek A, Bush D, Cornelius J, Guarino L, Kindt R, Orwa C, Russell J, Jamnadass R ,2013. What is the relevance of smallholders' agro forestry systems for conserving tropical tree species and genetic diversity in circa situm, in situ and ex situ settings? A review.BiodiversConserv 22(2):301–324.

Ensermu Kelbessa and Teshome Soromessa, 2008.Interference of regeneration, structure, diversity and use of some woody species in Bonga forest.Unique gene reserve for wild coffee. SINET: Ethiopia Journal of Sciences 31` (2):121-134.

EPA (Environmental Protection Authority), 2003.State of environment report of Ethiopia. The Federal Democratic Republic of Ethiopia. Addis Ababa, Ethiopia.166pp.

Fantaw, Y, Stig, L., and Abdu, A., (2008). Concentrations of exchangeable bases and cation exchange capacity in soils of cropland, grazing and forest in the Bale Mountains, Ethiopia. Forest Ecology and Management, 256, 1298-1302 plantation. Agro forestry System, 72, 103–115.

FayeraSenbeta and TeketayDemel, 2001.Regeneration of indigenous woody species under the canopies of tree plantations in Central Ethiopia.*Tropical Ecology*, 42: 175- 185.

FayeraSenbeta and Denich, M., 2006.Effects of wild coffee management on species diversity in the Afromontane rainforests of Ethiopia.For. Ecol. Manage. 232, 68–74.

Fekadu, G., Teshome, S., Ensermu, K., 2012. Structure and regeneration status of KomtoAfromontane moist forest, East Wollega Zone, west Ethiopia, *Journal of Forestry Research* 23(2): 205−216.

Food and Agriculture Organization (FAO), 2010.Global forest resources assessment-Forestry Department Food and Agriculture Organization of the United Nations.FRA2010/065 Rome.

FAO & WFP, 2006.FAO ⁄WFP Crop and Food Supply Assessment Mission to Ethiopia.Special report, Food and Agricultural Organization of the United Nations (FAO) and World Food Programme (WFP), Rome.

FFA Forestry, 2010. Forestry CDE State: Tree Measurement and Cruising Materials.

GeneneAsseffa, TeferaMengistu, ZerihunGetu and SollomonZewdie, 2013. Training Manual on: Forest Carbon Pools and Carbon Stock Assessment in the Context of SFM and REDD+. Wondo Genet, Ethiopia.

Gordon C, Manson R, Sundberg J, AngonAC, 2007. Biodiversity, profitability, and vegetation structure in Mexican Coffee agro ecosystem. Agriculture, Ecosystems and Environment 118:256–266.

Gurmessa, F., Soromessa, T., and Kelbessa, E. 2012.Structure and Regeneration status of KomtoAfromontane Moist forest, East Wellega Zone, West Ethiopia. *Journal of Forestry Research*, 23 (2): 205-216.

Heywood, V.H. 1995. An introduction. In: Heywood, V.H. and Watson, R.T. (eds.). Global

Biodiversity Assessment. UNEP, Cambridge University Press, Cambridge.

Hylander K, NemomissaSileshi, Delrue J, EnkosaWoldeyohannes, 2013. Effects of coffee management on deforestation rates and forest integrity.ConservBiol 27(5):1031–1040.

ICO, 2012.International Coffee Organization - World Coffee Trade [WWW Document]. URL
http://www.ico.org/countries/ethiop.

IPCC, (2002).Climate Change and Biodiversity.(Edited by Habiba G., Avelino S., and Robert T. W.)

Kindt R, Boffa JM, Lengkeek AG, Degrande A, Mbosso C, Van O D ,2008. Tree Species Diversity in Cultivated Landscapes: Investigation of Biodiversity Patterns through Training of African Researchers. ICRAF, Nairobi.

Kittesa Hundera, 2007. 'Traditional Forest Management Practices in Jimma Zone, South West Ethiopia', *Ethiopian Journal of Education and Science*, 2(2), pp. 1–10.

Kittesa Hundera and Tsegaye Gadissa, 2008.Vegetation Composition and Structure of the Belete Forest, Jimma Zone, South Western Ethiopia.*Ethiop. J. Biol. Sci.* 7(1): 1-15.

Kitessa Hundera, 2016. Shade Tree Selection and Management Practices by Farmers in Traditional Coffee Production Systems in Jimma Zone, Southwest Ethiopia.

Kufa, T. (2012).Recent coffee research development in Ethiopia.*Prensented at Ethiopian Coffee Export Conference: Strengthening the Legacy of Our Coffee.* Hilton, Addis Ababa.

Lal, R., (2004). Soil carbon sequestration to mitigate climate change; science direct, Elsevier, Ohio state university, Columbus, USA.

Likassa, E. 2014. Diversity of Shade Tree Species in Smallholder Coffee Farms of Western Oromia, Ethiopia. *African Journal of Geo-Science Research*, **3(1)**:01-03.

Martin Kent and Paddy Coker, 1992. Vegetation Description and Analysis: A practical approach. John Wiley and Sons, Chichester. 363p.

Magurran, A.E., 2004. Measuring biological diversity.Blackwell Sciences, Oxford.

McDonagh, J.F., Thomsen, T.B. and Magid, J., (2001). Soil organic matter decline and compositional change associated with cereal cropping in southern Tanzania. Land degradation & Development, 12, 13-26.

MELCA Mahiber, 2008. Communal Forest Ownership: An Option to Address the Underlying

Causes of Deforestation and Forest Degradation in Ethiopia? Proceeding of a workshop held at Chilimo Forest and Ghion Hotel November 25-27/2008. 43pp.

Mendez V, Bacon CM, Olson M, Morris KS, Shattuck A, 2010. Agro biodiversity and shade coffee smallholder livelihoods: a review and synthesis of ten years of research in Central America. Prof Geogr 62(3):357–376.

Mohan, S. and Love, J. 2004. Coffee futures: role in reducing coffee producers' price risk. J. Inter. Develop.16, 983–1002.

MohdNazipSuratman, 2012. Tree Species Diversity and Forest Stand Structure of Pahang National Park, Malaysia: Faculty of Applied Sciences, University of Technology MARA, Shah Alam, Malaysia.

Molla, A. and Asfaw, Z. 2014. Woody species diversity under natural forest patches and adjacent enset-coffee based Agroforestry in the Midland of Sidama Zone, Ethiopia. *Biodiversity and Conservation*, 6 (10**)**:708-723.

Motuma, T., Zebene, A., Mulugeta, L., and Karltun, E., (2008).Woody species diversity in a changing landscape in the south-central highlands of Ethiopia. Agriculture, Ecosystems and Environment 128:52–58.

Moreno-Casasola, P., Mata, D.I., Madero-Vega, C., Castillo-Campos, G. and Warner, B.G. 2011.Floristic composition and soil characteristics of tropical freshwater-forested wetlands of Veracruz on the coastal plain of the Gulf of Mexico. *Forest Ecology and Management*, 262: 1514-1531.

Mueller-Dombois, D. and Ellenberg, H. 1974.Aims and methods of vegetation ecology.

MuletaDirriba, Assefa F. Nemomissa S. and Granhall U. 2011. Socioeconomic Benefits of Shade Trees in Coffee Production Systems in Bonga and Yayuhurumu Districts, Southwestern Ethiopia: Farmers' Perceptions. Ethiopian Journal of Education and Sciences **7:**39-56.

Mulugeta, L., (2004). Effects of land use changes on soil quality and native flora degradation and restoration in the highlands of Ethiopia.

Nabuurs, G. J., Paivinen, R., Sikkema, R. and Mohren, G. M. J., (1997).The role of European forests in the global carbon cycle - a review'. Biomass and Bioenergy, 13, 345-358.

Nair, P. K., (1993). An Introduction to Agroforestry. Dordrecht, the Netherlands, Kluwer Academic Publishers.

Nair, P. K., Kumar, B. M., & Nair, V. D., (2009).Agroforestry as a strategy for carbon sequestration. Journal of Plant Nutrition and Soil Science, 172: 1, 10-23.

OmersherifJemal, Daniel Calloo-Concha, and MeinevanNoorwdwijk, 2018.Local agroforestry practices for food and nutrition security of small holder farm households in south western Ethiopia.

Perfecto, I., Rice, R.A., Greenberg, R., VanderVoort, M.E., 1996. Shade coffee: a disappearing refuge for biodiversity. Bioscience 46, 598–608.

Perfecto I, Vandermeer J, Mas A, Pinto S L, 2005. Analysis biodiversity, yield, and shade coffee certification. Ecological Economics 54:435-446.

Philpott M, 2010. Investigating the effects of shade canopy management on natural enemies, pests, plant damage, and yield in organic coffee plantations. Organic Farming Research Foundation Report, December 2010.

Pinard F, Joetzjer E, Kindt R, Kehlenbeck K, 2014. Are coffee agroforestry systems suitable for circa situm conservation of indigenous trees? A case study from Central Kenya.BiodiversConserv 23(2):467–495.

RafAerts, Hundera, K., Berecha, G., Gijbels, P., Baeten, M., Van Mechelen, M., Hermy, M., Muys, B., Honnay, O., 2011.Semi-forest coffee cultivation and the conservation of Ethiopian Afromontane rainforest fragments.For. Ecol. Manage. 261, 1034–1041.

RegassaFayissa, 2001.Forest resource ownership and use rights and the role of communities in forest management: in imperative problems associated with forests in Ethiopia proceeding of a work shop organized by biological society of Ethiopia Feb, 1, 2001.

Russell A Mittermeier, Robles Gil, P., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier,
C.G., Lamoreux, J. & Da Fonseca, G.A., 2004. Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions. CEMEX, Mexico City.

Schmitt, C.B., 2006. Montane Rainforest with Wild Coffee Arabica in the Bonga Region (SW Ethiopia): Plant Diversity, Wild Coffee Management and Implications for Conservation. Ecology and Development Series, No. 48, CuvillierVerlag, Go¨ttingen.

Shibru, S. and Balcha, B. 2004.Composition, structure and regeneration status of woody species in Dindin Natural Forest, Southeast Ethiopia; An implication for conservation.*Ethiopian Journal of Biological Science,* 3:15-35.

ShirindhiAmbinakudige and Sathish BN, 2009.Comparing tree diversity and composition in coffee farms and sacred forests in the Western Ghats of India.Biodivers. Conserve. 18:987-1000

ShoniiBhagwat SA, Willis KJ, Birks HJB and Whittaker RJ, 2008. Agroforestry: a refuge for tropical biodiversity? Trends EcolEvol 23(5):261–267.

Somarriba, E., Harvey, C., Samper, M., Anthony, F., Gonzalez, J., Staver, C., Rice, R., 2004.Biodiversity in coffee plantations. In: Schroth, G., Fonseca, G., Harvey, C., Gascon, C., Vasconcelos, H., Izac, A.M.N.

Steffan-Dewenter I, Kessler M, Barkmann J et al., 2007.Tradeoffs between income, biodiversity, and ecosystem functioning during tropical rainforest conversion and agroforestry intensification. PNAS 104(12):4973–4978.

Tadesse, G., Zavaleta, E., Shennan, C. &FitzSimmons, M. (2014). Policy and demographic factors shape deforestation patterns and socio-ecological processes in southwest Ethiopian coffee agroecosystems.*Applied Geography,* 54(0)**,** 149-159.

Tadesse, W.G., Denich, M., Demel, T., and Vlek, P.L.G., (2002).Human impacts on Coffee arabica genetic pool in Ethiopia and the need for its in situ conservation. In: Managing plant genetic diversity (J. Engels, V. RamanathaRao, A.H.D. Brown, and M. Jackson, Eds). CAB International / IPGRI. 237-247.

TeketayDemel, 1999. History, botany and ecological requirements of coffee.Walia 20, 28–50.

Tesfaye Amare, 2007. Plant Diversity in Western Ethiopia: ecology, Ethno botany present for degree of PhD.

Tengnas B, 1994. Agroforestry extension manual for Kenya. ICRAF, Nairobi, Kenya

Todo, Y. and Takahashi Ryo., 2011. Impact of Farmer Field Schools on Agricultural Income and kills: Evidence from an Aid-Funded Project in Rural Ethiopia.162–8433, Tokyo JAPAN.

TolaGamechu, 2016. Ecosystem services and disservices in an agriculture forest mosaic: A study of forest tree management and land scape transformation in south western Ethiopia.

UNDESA, 2004.United Nation Development of Economic and Social Affairs. Agenda 21: Combating Deforestation Program United Nations http://www.un.org/esa/inde.htm/.

William Cochran, 1977. Sampling Techniques: Third edition, New York: John Wiley and Sons.

WoldemariamGole. Denich, Demel T .and Vlek, P.L.G. 2002.Human impacts on *Coffea Arabica* genetic pool in Ethiopia and the need for its *in situ* conservation. In: J. Engels, V. RamanathaRao, A (eds.): Managing plant genetic diversity. Pp 237-247.

WoldemariamGoleBorch, T., Denich, M. &Teketay, D., 2008.Floristic composition and environmental factors characterizing coffee forests in southwest Ethiopia.*Forest Ecology and Management*, 255(7)**,** 2138-2150.

Woldemariam Tadesse. , 2003. Vegetation of the Yayu Forest in SW Ethiopia: Impacts of Human use and Implications for in Situ Conservation of Wild Coffea Arabica L.
Populations.Ecology and Development Series No. 10, CuvillierVerlag, Go¨ttingen.

Worku, A., Teketay, D., Lemenih, M. and Fetene, M. 2012.Diversity, regeneration status, and population structures of gum and resin producing woody species in Borana, Southern Ethiopia.

Young, A., (1997). Agroforestry for Soil Management, 2nd ed. CAB International, Wallingford.

6. APPENDIX

6. APENDIX

Appendix 1. Household survey questionnaires

Household Identification and their socio-economic condition
Part I: general information

Date of interview____________Month __________ year ____________________

District ______________ Forest type____________ site/sub village____________

Part I-General background information

1. Code of respondents____________, Date of the interview___________
2. Name of respondents ____|________________, Age _________ Sex _
3. Family size _____ Female ______Male________
4. Marital status. 1. Married; 2. Single; 3. Divorced; 4. Widowed
5. Educational status: 1. Illiterate, 2. Grade 1-4, 3. 5-8 grade, 4. Grade 9-12; 5. Above grade 12
6. Occupational status: 1. Crop production; 2.Livestock rearing; 3. both crop production and livestock rearing; 4. vegetable production and small scale trade; 5. others (please specify)
7. Wealth categorization: 1. Reach; 2. Medium; 3. Poor
8. Total land holding size ________________ha

Source of income	Now	
	Tick mark	Proportion of income
Live stock rearing		
Crop production		
Both live stock rearing and crop production		
Vegetable and frout production		
Small scale trading		
Wage labor		
Beekeeping		
Forest coffee collection		
Hunting		
Spice, leaves and tuber collection from forest		
Woody species		

Part II: woody species access to household survey questionnaire

1. **How do you rate semi forest coffee and natural forest use?**

Access use	Natural forest	Semi-forest coffee
Timber (restricted/common)		
Ownership feeling(private/common)		
House hold benefit(low/high)		

Do you use the natural forest now? 1) Yes 2) No, If Yes for what purpose ___________ or No why_________________

2. **Woody species usage in natural forest and semi-forest coffee**

No	Species local name	Type of uses	Part of uses	Site	
				Natural forest	Semi-forest coffee

3. How do you describe the status of existing woody species under semi-Coffee forestry and natural forest with previous times?

Indicators (decreasing, increasing, no change)	Current status semi-forest coffee				Natural forest		
	Main reason	Dec.	Inc.	No change	Dec.	Inc.	No change
Forest area							
Woody Species composition							
Different timber products from woody species							

4. **Important woody Species in the area top ten.**

No	Species name		Use of species	
	Natural forest	Semi-forest	Natural forest	Semi-forest
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

5. **How do you prefer these woody species across semi-forest coffee and natural forest.**

No	Species name	Natural forest (decreasing, increasing, no change, lost)	Semi-forest coffee (decreasing, increasing, no change, lost)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

7. Other socioeconomic benefits of tree species from natural forest and semi forest coffee.

Usage	Natural forest		Semi-forest coffee	
	Yes	No	Yes	No
Firewood				
Honey production/beekeeping				
Improvement of soil fertility				
Reduction of soil erosion				
Reduction of hail/frost damage				
Medicinal value				
Timber production				
Biodiversity conservation				
Reduction of agrochemical inputs				

Appendix 2.Botanical name of woody species in natural forest

Botanical Name	Vernacular name (Afan Oromo)	Family	Growth habitat
Albizia gummifera	Hambabbeessa	*Fabaceae*	Tree
Macaranga	Halele	*Maytenusundata*	Tree
Asplenium protensum	Qawoo	*Aspleniaceae*	Liana
Allophylus abyssinicus	Se'o	Sapindaceae	Tree
Bersama abyssinica	Lolchiisaa	Melianthaceae	Shrub
Clausena anisata	Ulumaaye	Rutaceae	Shrub
Cordia Africana Lam.	Waddeessa	Boraginaceae	Tree
Croton macrostachyus	Bakanisa	Euphorbiaceae	Tree
Crotolaria mildbraedii	Yubdo	*Fabaceae*	Tree
Canthium oligocarpum	Miixoo	*Rubiaceae*	Tree
Dracaena afromontana	Emoo	Dracaenaceae	Shrub
Diospyros abyssinica	Lookoo	Ebenaceae	Tree
Ehretia cymosa	Ulaagaa	Boraginaceae	Shrub
Ekebergia capensis	Somboo	Meliaceae	Tree
Fagaropsis angolensis	Sigilu	Rutaceae	Tree
Ficus sycomorus	Harbuu	Moraceae	Tree
Ficus ovata	Dembii	Moraceae	Tree
Ficus vasta	Qilxuu	*Moraceae*	Tree
Galineria saxifrage	Simararuu	Rubiaceae	Shrub
Hippocratea Africana	Xiyoo	Celasteraceae	Lianas
Hippocratea pallens	Dikiicha	Celasteraceae	Lianas
Justicia schemperiana	Dhummuugaa	*Acantaceae*	Shrub
Landolphia buchananni	Yebo	Apocynaceae	Lianas
Maesa lanceolata	Abbayyii	Myrsinaceae	Shrub
Maytenus arbutifolia	Kombolcha	Celasteraceae	Shrub
Millettia ferruginea	Askira	Fabaceae	Tree
Mimusops kummel	Qolaatii	*Sapotaceae*	Tree

Vernonia auriculifera	Reji	*Asteraceae*	Tree
Chionanthus Mildbraedii.	Gajjaa	Oleaceae	Tree
Olea welwitschii	Baya	Oleaceae	Tree
Phoenix reclinata	Meexii	Arecaceae	Tree
Pittosporum viridiflorum	Soole	Pittosporaceae	Tree
Prunus Africanus	Homi	*Rosaceae*	Tree
Pouteriaadolfi-friederici	Qararo	*Sapotaceae*	Tree
Polyscias fulva	Kariyo	Araliaceae	Tree
Sapium ellipticum	Bosoqqaa	Euphorbiaceae	Tree
Schefflera abyssinica	Boto	Araliaceae	Tree
Syzygium guineense	Baddeessaa	Myrtaceae	Tree
Teclea nobilis	Hadheessa	Rutaceae	Shrub
Tiliacora troupinii	Liqixii	Menispermaceae	Lianas
Tecleanobilis	Mixirii	*Rutaceae*	Tree

Appendix 3. Botanical name of woody species in semi-forest coffee

Botanical Name	Vernacular name (Afan Oromo)	Family	Growth Habitat
Acacia abyssinica	Laaftoo	Fabaceae	Tree
Albizia gummifera	Hambabbeessa	Fabaceae	Tree
Bersama abyssinica	Lolchiisaa	Melianthaceae	Shrub
Clausena anisata	Ulumaaye	Rutaceae	Shrub
Coffea arabica.L	Buna	Rubiaceae	Shrub
Cordia africana Lam.	Waddeessa	Boraginaceae	Tree
Croton macrostachyus	Bakanisa	Euphorbiaceae	Tree
Crotolariamild braedii	Yubdo	*Fabaceae*	Tree
Rytigynia neglecta	Miixo	*Rubiaceae*	Tree
Diospyros abyssinica	Lookoo	Ebenaceae	Tree
Dracaena afromontana	Emoo	*Dracaenaceae*	Shrub
Ehretia cymosa	Ulaagaa	Boraginaceae	Shrub
Euphorbia candelabrum	Adamii		Tree

Fagaropsis angolensis	Sigilu	Rutaceae	Tree
Ficus sycomorus L	Harbuu	Moraceae	Tree
Galinieria saxifraga	Simararuu	*Rubiaceae*	Tree
Justicia schemperiana	Dhummuugaa	*Acantaceae*	Shrub
Maytenus gracilipes	Kombolcha	*Celastraceae*	Shrub
Millettia ferruginea	Askira	Fabaceae	Tree
Mimusops kummel	Kolaatii	*Sapotaceae*	Tree
Olea capensis L.	Gajjaa	Oleaceae	Tree
Phoenix reclinata	Meexii	Arecaceae	Tree
Polyscias fulva	Kariyo	Araliaceae	Tree
Sapium ellipticum	Bosoqqaa	Euphorbiaceae	Tree
Stereospermum kunthianum	Dhama''ee	Bignoniaceae	Tree
Syzygium guineense	Baddeessaa	Myrtaceae	Tree
Schefflera abyssinica	Bottoo	*Araliaceae*	Tree
Tecleanobilis	Mixirii	*Rutaceae*	Tree
Vepris dainelli	Hadheessa	*Rutaceae*	Tree

Appendix 4. Families of woody species in natural forest and semi-forest coffee

Natural forest		Semi forest coffee	
Families Names	No. Species %	Families Names	No. Species %
Rutaceae	10.3	Fabaceae	14.8
Fabaceae	7.7	*Rutaceae*	14.8
Celastraceae	7.7	Rubiaceae	7.4
Moraceae	7.7	Boraginaceae	7.4
Sapotaceae	5.1	Euphorbiaceae	7.4
Oleaceae	5.1	Araliaceae	7.4
Euphorbiaceae	5.1	Melianthaceae	3.7
Bignoniaceae	5.1	Ebenaceae	3.7
Maytenusundata	2.6	*Dracaenaceae*	3.7
Aspleniaceae	2.6	Moraceae	3.7

Sapindaceae	2.6	*Acantaceae*	3.7
Melianthaceae	2.6	*Celastraceae*	3.7
Rubiaceae	2.6	*Sapotaceae*	3.7
Dracaenaceae	2.6	Oleaceae	3.7
Ebenaceae	2.6	Arecaceae	3.7
Meliaceae	2.6	Bignoniaceae	3.7
Acantaceae	2.6	Myrtaceae	3.7
Apocynaceae	2.6		
Myrsinaceae	2.6		
Asteraceae	2.6		
Oleaceae	2.6		
Arecaceae	2.6		
Pittosporaceae	2.6		
Rosaceae	2.6		
Araliaceae	2.6		
Myrtaceae	2.6		
Menispermaceae	2.6		

Appendix 5. Relative frequency, Relative dominance, and important value index of woody species in natural forest

Botanical Name	RD	RF	RA	IVI
Albizia gummifera	2.676	3.074	1.565	7.315
Albzia grandibracteata	1.313	4.191	2.535	8.037
Aspleniumprotensum	0.145	1.677	0.298	2.119
Allophylus abyssinicus	0.494	0.838	1.267	2.599
Bersama abyssinica	2.218	4.749	3.129	10.098
Clausena anisata	0.116	0.838	0.298	1.253
Cordia africana Lam.	2.605	3.632	2.236	8.473
Croton macrostachyus	11.102	7.266	3.129	21.496
Crotolaria mildbraedii	4.461	5.868	3.502	13.831
Canthium oligocarpum	2.089	6.426	2.534	11.049
Dracaena afromontana	1.948	7.265	2.236	11.448
Diospyros abyssinica	1.979	5.029	2.832	9.84
Ehretia cymosa Thonn.	4.338	1.956	2.236	8.529
Ekebergia capensis	0.079	0.2794	0.0746	0.434
Fagaropsis angolensis	1.128	3.353	0.894	5.375
Ficus sycomorus L	1.198	3.0735	2.236	6.507
Ficus thonningii	0.13	0.279	0.075	0.484
Ficus vasta	0.563	0.279	0.075	0.917
Galineria saxifraga	1.045	1.397	1.267	3.708
Maytenus arbutifolia	0.477	1.118	0.894	2.489
Millettia ferruginea	3.762	4.749	3.8	12.312
Mimusops kummel	0.578	3.632	0.596	4.807
Olea capensis L.	19.732	8.382	29.061	57.175
Olea welwitschii	1.157	1.677	0.596	3.429
Phoenix reclinata	4.769	0.559	2.236	7.563
Pouteriaadolfi-friederici	2.765	0.559	0.298	3.622
Polyscias fulva	0.058	0.279	0.149	0.486
Sapium ellipticum	1.249	4.191	0.298	5.739

Schefflera abyssinica	3.807	0.838	0.298	4.943
Syzygium guineense	1.475	1.397	1.267	4.138
Teclea nobilis	12.141	2.794	15.648	30.584
Tecleanobilis	8.343	8.382	12.444	29.169

Appendix 6. Relative frequency, Relative dominance, and important value index of woody Species in semi forest coffee

Botanical Name	RD	RF	RA	IVI
Albizia gummifera	2.987	6.893	6.087	15.967
Bersama abyssinica	2.073	8.863	11.739	22.675
Clausena anisata	0.033	1.969	0.579	2.583
Cordia africana Lam.	3.249	4.431	3.623	11.303
Croton macrostachyus	7.692	5.908	4.928	18.528
Crotolariamild braedii	1.266	4.431	2.464	8.161
Canthium oligocarpum	0.394	4.924	2.464	7.781
Diospyros abyssinica	3.968	9.355	5.507	18.83
Dracaena afromontana	0.337	1.477	1.159	2.974
Ehretia cymosa	0.209	1.477	0.579	2.266
Euphorbia candilabrum	0.588	0.492	0.725	1.805
Fagaropsis angolensis	0.601	4.431	3.044	8.076
Ficus sycomorus L.	7.204	1.969	1.159	10.333
Galinieria saxifraga	1.273	2.954	3.623	7.85
Maytenus gracilipes	0.929	2.462	9.275	12.666
Millettia ferruginea	4.263	3.939	8.697	16.898
Olea capensis L.	0.356	8.37	7.971	16.697
Phoenix reclinata	1.329	1.477	0.725	3.531
Polyscias fulva	0.033	1.477	0.579	2.09
Sapium ellipticum	22.809	2.462	1.739	27.01
Syzygium guineense	11.121	4.924	3.623	19.667
Schefflera abyssinica	23.502	2.954	0.579	27.036
Tecleanobilis	0.201	4.431	3.623	8.255
Vepris dainelli	3.576	7.878	15.507	26.962

Appendix 7. Regeneration status of woody species in natural forest and semi-forest coffee

Natural forest		Semi forest coffee	
Botanical Name	**Regeneration Status**	**Botanical Name**	**Regeneration Status**
Albizia gummifera	Fair	*Acacia abyssinica*	No regeneration
Albsia grandibracteata	Fair	*Albizia gummifera*	Poor
Asplenium protensum	Fair	*Bersama abyssinica*	Fair
Allophylus abyssinicus	Fair	*Clausena anisata*	Good
Bersama abyssinica	Fair	*Coffea arabica.L*	Good
Clausena anisata	Fair	*Cordia africana Lam.*	No regeneration
Cordia africana Lam.	No regeneration	*Croton macrostachyus*	Poor
Croton macrostachyus	Fair	*Crotolariamild braedii*	Good
Crotolaria mildbraedii	Fair	*Canthium oligocarpum*	No regeneration
Canthium oligocarpum	Fair	Diospyros abyssinica	No regeneration
Dracaena afromontana	Fair	*Dracaena afromontana*	Poor
Diospyros abyssinica	Good	Ehretia cymosa	Poor
Ehretia cymosa	Good	*Euphorbia candilabrum*	No regeneration
Ekebergia capensis	No regeneration	Fagaropsis angolensis	No regeneration
Fagaropsis angolensis	No regeneration	Ficus sycomorus L.	No regeneration
Ficus sycomorus	Good	*Galinieria saxifraga*	Good
Ficus thonningii	No regeneration	*Justicia schemperiana*	Poor
Ficus vasta	No regeneration	*Maytenus gracilipes*	Fair
Galineria saxifraga	Good	Millettia ferruginea	Fair
Hippocratea africana	Fair	*Mimusops kummel*	Poor
Hippocratea pallens	Poor	Olea capensis L.	No regeneration
Justicia schemperiana	Good	Phoenix reclinata	No regeneration
Landolphia buchananni	Fair	Polyscias fulva	No regeneration
Maesa lanceolata	Fair	Sapium ellipticum	No regeneration
Maytenus arbutifolia	Fair	Stereospermum kunthianum	Poor
Millettia ferruginea	Fair	Syzygium guineense	No regeneration

Mimusops kummel	Poor	*Schefflera abyssinica*	No regeneration
Myrica salicifolia	Good	*Tecleanobilis*	No regeneration
Olea capensis	Fair		
Olea welwitschii	No regeneration		
Phoenix reclinata	Good		
Pittosporum viridiflorum	Fair		
Prunus africanus	No regeneration		
Pouteriaadolfi-friederici	Poor		
Polyscias fulva	No regeneration		
Sapium ellipticum	Poor		
Schefflera abyssinica	No regeneration		
Syzygium guineense	Poor		
Teclea nobilis	Fair		

Appendix 8: Pictures taken during field survey and soil laboratory analysis