WOODY SPECIES DIVERSITY, REGENERATION AND SOCIOECONOMIC BENEFITS UNDER COFFEE AGROFORESTRY AND NATURAL FOREST: THE CASE OF BELETE FOREST, SOUTHWEST ETHIOPIA

MSc. THESIS

HANA YASIN HASSEN

JUNE 2016

JIMMA, ETHIOPIA

WOODY SPECIES DIVERSITY, REGENERATION AND SOCIOECONO MIC BENEFITS UNDER COFFEE AGROFORESTRY AND NATURAL FOREST: THE CASE OF BELETE FOREST, SOUTHWEST ETHIOPIA

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 (Forest and Nature Conservation)

By

Hana Yasin Hassen

June 2016

Jimma, Ethiopia

DEDICATION

I dedicate this thesis manuscript to my mother Kedija Abdulkerim and my father Yasin Hassen for their dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOR

First I declare that this thesis is my work and that all sources of the materials used for this thesis have been duly acknowledged. This thesis has been submitted to in partial fulfillment of the requirements for M.Sc. degree at Jimma University, College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made 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: Hana Yasin

Signature____________

Place: Jimma University

Date of submission: _____________

BIOGRAPHICAL SKETCH

Hana Yasin was born on September 4, 1991 in Dembi Dollo town, Kellem Wollega Zone, Oromia National Regional State, Ethiopia. She attended her education at Olika Dingle Primary School and Kelem Secondary and Preparatory School. Hana has attended her undergraduate study at Jimma University College of Agriculture and Veterinary Medicine and received BSc in Natural Resource Management in June 2013. After graduation, she immediately joined the School of Graduate Studies at Jimma University to pursue her study leading to the Master of Science in Natural Resource Management (Forest and Nature Conservation).

ACKNOWLEDGEMENT

Above all, I am very much grateful to almighty ALLAH, who is always with me in all my steps and has helped me to complete my thesis work. I am also very grateful to my advisors Mr. Zerihun Kebebew and Dr. Kitessa Hundera for their unreserved and continuous encouragement, guidance, diligent follows up of my progress and valuable effort in every step of the thesis work. This thesis would have not been complete without their assistance.

I would like to thank my mother Kedija Abdulkerim for financial and moral support she has cherished me during the study period. Her encouragement has strengened me to to complete my study in due time. Jimma University has also financed my thesis work and I am very much grateful for that.

My heartfelt appreciation also goes to my friends, Teferi Mekuria and Mehaba Seifu for their support during the fieldwork. Special thanks also goes to Mitiku Tezera, for his technical help during the field survey, Hussein Abdal and Abba Biya Jamal for devoting their precious time in facilitating my fieldwork. I am grateful to the development agents of the districts indeed.

I would also like to extend my special thanks to my mother and father who sent me to school for the opportunity of education at early stage, which they did not get the opportunity for themselves. Their role in my academic success is surely beyond my comprehension. Therefore, I owe my mom and dad a lot who have stood by me since my early school age until today. In addition my all dearest sisters and brothers: Nura, Amal, Sadiya, Yusuf, Arafat and Hassen for their concern and follow up, praise worthy, support and encouragement have helped me to effectively complete my study.

TABLE OF CONTENTS

Contents **Pages**

LIST OF ABBRIVIATIONS AND ACRONYMS

CSA	Central Statistical Agency
DBH	Diameter at Breast Height
ETB	Ethiopian Birr
HHs	Households
IVI	Importance Value Index
NTFP	Non-timber Forest Products
RFI	Relative Forest Income
SDI	Simpsons Diversification Index
SNNPRS	South Nation Nationalities People Reginal State
SPSS	Statistical Package for Social Sciences Software
S_s	Sorensen’s similarity index

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX

ABSTRACT

Conversion of forest to agriculture has already been taking place in southwest Ethiopia. Many of biodiversity are conserved in agricultural landscapes. In the long-term conservation of native species, higly depends on agricultural landscapes. Coffee agroforestry has been promoted as a means for preserving biodiversity in the tropics. The study was conducted to investigate species composition, diversity, regeneration, and socioeconomic benefits of natural forest and coffee agroforestry at Belete forest. Vegetation data were collected from natural forest and coffee agroforestry study site. A total of 68 plots (34 plots in each sites), having an area of 20 m x 20 m for trees, 10 m x 10 m for saplings and 5 m x 5m for seedlings were laid along transect at a distance of 100m between each transects lines and plots. Household survey was conducted to collect socioeconomic benefits of natural forest and coffee agroforestry. A total of 136 households (68 households for each sites) were randomly selected for the interview to collect socioeconomic benefits. The collected data from woody species and household survey were analyzed using Statistical Package for Social Sciences version 20 for different statistical purpose.The results showed that a total of 55 woody species belonging to 35 families in natural forest and 33 woody species belong to 23 families in coffee agroforestry were identified and recorded. Although more woody species were recorded under the natural forest, the difference was not statistical significant ($p>0.05$). The species richness and Shannon diversity index of woody species between natural forest and coffee agroforestry were not statistically also significantly ($p>0.05$). Regeneration status of seedling and sapling of woody species had showed significant ($P<0.05$) differences between the natural forest and coffee agroforestry. However, there was no statistically different ($p > 0.05$) between the natural forest and coffee agroforestry interms of tree composition. The socioeconomic benefit result shows that diversity of forest products that can be obtained from the two were not statistically significant difference ($p>0.05$). However, the forest income in a form NTFPs and Simpsons Diversification Index of household's were significant differnece ($p < 0.05$) between natural forest and coffee agroforestry. Coffee agroforestry contributes to conservation of woody species through retention woody species and reducing pressure on the natural forest, which may be a reflection of conservation of biodiversity and economic values of the forest that promote sustainable uses of the forest and its products. Therefore, conservation of woody species and socioeconomic benefits must be linked in the arena of conservation approaches.

Key words**:** Woody species, diversity, livelihood forest incomes, socioeconomic benefits

1. INTRODUCTION

1.1. Background information

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

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

Neverthless, coffee agroforestry is said to conserve high biodiversity and offer much greater conservation value (Komar, 2006). For instances, shaded coffee production system has received considerable attention from conservation organizations in recent years in which it supports biodiversity and cash income generation from the sale of forest products (Gordon *et al*., 2007).

Due to coffee is the understory of the forest many woody species are conserved together with shade coffee production (Stills *et al*., 2012).

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

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

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). Converting natural forest to different agroforestry systems has some drawbacks. However, the role of coffee agroforestry adjacent to the natural in conserving woody species, providing socioeconomic benefits and reducing pressure on the natural forest are less studied. The patterns of population structures, regeneration and diversity could providing valuable information for conservation strategies. Therefore, this study was aimed at provide relevant information, which is of paramount importance to undertake on diverse range of economic, ecological information about the natural forest and coffee agroforestry necessary to design suitable conservation and sustainable use approaches. In addition, provide information about forest product, access and livelihood diversifications have important implications for development and practice.

1.2. Objective of the Study

1.2.1. General objective

- To investigate woody species diversity, regeneration status and socioeconomic benefits under natural forest and coffee agroforestry

1.2.2. Specific objectives

- To compare woody species composition, diversity, structure and regeneration under natural forest and coffee agroforestry
- To compare socio-economic benefits from natural forest and coffee agroforestry

1.3. Research Question

- Is there a major change in species composition, structure, regeneration and diversity between a natural forest and coffee agroforestry?
- Does more diversity imply more socio-economic benefits?

2. LITERATURE REVIEW

2.1. Biodiversity Conservation

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

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

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

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

2.2. Role of Coffee Agroforestry

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

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

2.2.1. Woody species conservation

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

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

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

2.2.2. Socio-economic benefits

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

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

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

3. MATERIAL AND METHODS

3.1. Description of Study Area

The study was conducted at Belete forest, which is located in Shabe Sombo district of Jimma Zone, southwestern Ethiopia. It is found along Jimma-Bonga main road at 50 km from Jimma town. Geographically it is found between 7° 30' N, 7°45’ N latitudes, 36° 15’ E, and 36°45’ E longitudes (Fig. 1).

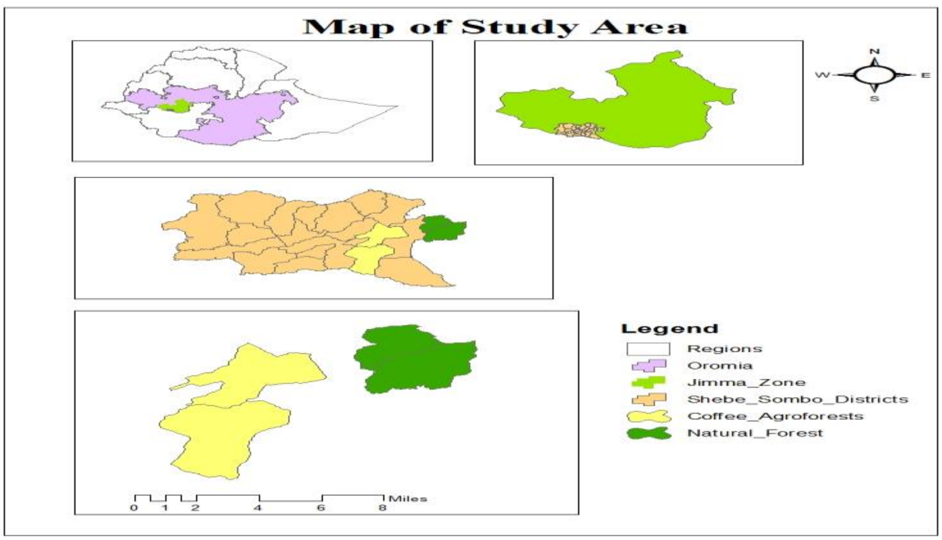

Figure 1: Map of the study area

The physiographic land feature of Belete forest area was formed by the volcanic activities, erosion and deposition and the underlying geology with some local structural influence. The area is characterized by a rugged topography, dominated by gentle slopes and a localized steep slopes ranging from 4 - 45%. Several small streams cross the area. The altitude ranges 1,300 - 3,000 meter above sea level (Cheng *et al.*, 1998). The annual precipitation ranges from 1800 to 2300 mm with maximum rainfall between the months of June and September. The mean annual minimum and maximum annual temperature of the area ranges is 15^0 C and 22^0 C, respectively (Hundera and Gadissa, 2013).

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 significantly between 1985-2010 period (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 *Syzigium guineense*, *Olea welwitschii*, *Prunus africana* and *Pouteria adolfi-friederici* (Demissew *et al*., 2004).

Belete-Gera forest is under Participatory Forest Management regime commenced in October 2003. Community-driven forest management associations; improving agricultural technologies and practices through farmer field schools and livelihood support through the Forest Coffee Certification Program. The Rainforest Alliance certified coffee-producing households started in 2007. 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.

According to CSA (2014), national census report the total population of this district of 134,442 of which 67,866 (51%) males and 66,576 (49%) female. Forest area 7983 households live a total population around 38,571. About 76.83% are Muslim, while 21.26% Orthodox Christianity and 1.77% were Protestant. The area is characterized by a mid-land, mixed agriculture, moderately productive, food sufficient area. Forest residents are mostly farmers, producing cereals such as wheat, barley, and teff, as well as vegetables, honey, milk, coffee and chat.

3.2. Methods

3.2.1. Study site selection

Belete forest was purposively selected due to the presence of both natural forest and coffee agroforestry. Fourteen villages surround the forest, seven of the villages are bordering the natural forest and the other seven villages are bordering the coffee agroforestry. Four villages (two from each) were selected randomly; Atro Gefere and Sombo Daru for the natural forest whereas, Yanga Duguma and Sebeka Debye for coffee agroforestry.

3.2.2. Vegetation data collection

Vegetation data were collected along the transect line. A total of 68 plots (34 plots for natural forest and 34 plots for coffee agroforestry) with an area of 20 m x 20 m were established along transects and the distance between plots and transects lines 100 m. Total of fourteen transects were laid down (seven transect line for natural forest and seven for coffee agroforestry). In each transects line five plots were estabilished. Within the main plots, a subplot of 10 m x 10 m and 5 m x 5 m was nested for saplings and seedlings assessment respectively. The starting point of the first transect line was located randomly. To avoid edges effects all sample plots were established at least 50 m from forest the edges or roads inside the forest (Senbeta and Teketay, 2001).

Height and Diameter at Breast Height (DBH) were measured for all woody species in the plot with height ≥ 2 m and DBH ≥ 10 cm thick. Clinometer and diameter tape were used to measure the height and DBH respectively. In each plot, all naturally regenerated woody species were identified and counted. Woody species with height $\leq$ 50 cm and DBH $\leq$ 10cm and height $>$ 50cm and DBH $\leq$ 10 cm were counted as seedlings and saplings respectively (Kelbessa and Soromessa, 2008). Local name (Afan Oromo) of woody species was identified with the help of local communities in the field. Plant specimens were collected, pressed, dried and brought to Jimma University department of biology for further identification and deposited. 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. Socio-economic information data collection

Socioeconomic information was collected on the benefits of natural forest and coffee agroforestry of households. It focused on household's characteristics, forest income in a form of non-timber forest products (NTFP), forest products and forest utilization pattern. Structured and semi structured questionnaire was prepared to collect the information. Information was collected through household interview. The secondary data source was gathered form district's Administration office and Rural and Agricultural development office. 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 136 households were sampled for this study (Table 1). The households for interview were selected based on simple random sampling techniques.

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

Where;

$n_{o=}$ Desired sample size when population greater than 10,000

n_1= 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 1: Sample size determination of households

Name of Kebele	Total HHs	Sample Size
Yanga Duguma	499	31
Sebeka Debye	694	43
Atero Gefere	540	33
Sombo Daru	467	29
Total HH	2200	136

3.3. Vegetation 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 asssements.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).

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 the i^{th} species

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

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

Where:

E= Equitability (evenness) index which has values between 0 and 1

H' = Shannon Diversity

$H'_{max=}$ Maximum level of diversity possible within a given population

Pi = Proportion of individuals found in the i^{th} species

S = Total number of species (1, 2, 3…..s)

3.3.3. Sorensen's similarity index

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

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

Where, S_s = Sorensen's similarity index

A = number of species in sample one

B = number of species in sample two

C = number of species common to both sample.

3.3.4. Important value index (IVI)

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

$$\text{IVI} = \text{Relative dominance} + \text{Relative frequency} + \text{Relative Abudance}$$

Basal area

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

$$BA = \frac{\pi \times DBH^2}{4}$$

Where, = basal area (m^2), DBH= diameter at breast height (cm); $\pi = 3.14$

Dominance

It refers to the degree of coverage of a species as an expression of the space it occupied in a given area. Usually, dominance is expressed in terms of basal area of the species (Kent and Coker, 1992). Two set of dominance were calculated in this case: dominance (the sum of basal areas of the individuals in m^2/ha), and relative dominance, which is the percentage of the total basal area of a given species out of the total measured stem basal areas of all species.

$$\text{Dominance} = \frac{\text{Total basal area}}{\text{Area sampled}}$$

$$\text{Relative dominance} = \frac{\text{Dominance of species A}}{\text{Total dominance of all species}} * 100$$

Frequency

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

$$\text{Frequency of species} = \frac{\text{Number of plots in which that species occurs}}{\text{Total number of plots}} * 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of species A}}{\text{Total frequency of all species}} * 100$$

Abundance

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

$$\text{Relative abundance} = \frac{\text{Number of individuals of species}}{\text{Total number of individuals}} * 100$$

Density

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

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

3.3.5. Community structure

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

i) Seedling > sapling > tree/shrub state, pattern represents good regeneration
ii) Seedling outnumbers sapling and tree/shrub state but sapling less than tree/shrub state pattern fair regeneration
iii) Seedling < sapling < tree/shrub state, this pattern shows poor reproduction and hampered regeneration
iv) With no individual in seedling and sapling stages but relatively many individuals in tree/shrub stage pattern shows poor reproduction and hampered regeneration

3.4. Socio-Economic Data Analysis

3.4.1. Forest product diversity index

The Shannon diversity index was calculated to measure forest products from natural forest and coffee agroforestry. Shannon diversity index was commonly used in ecology but has been applied to forest products diversity as economic diversity index (EDI). The formula of EDI is follow:

$$\text{EDI} = -\sum_{pi} \ln(pi)$$

Where:

pi = proportion of households in a village that rely on each main source forest products

N= number of main sources forest products

A household is classified into one category based on its main income source and p_i's add up to one. The index ranges from zero to ln (n). In a village where all households have the same main source, EDI = Zero. Where there is an even distribution of all possible main sources among households in a village (Dewi *et al.*, 2005).

3.4.2. Measurement of household income diversification index

Diversification index was measured with the help of Simpson diversity index by using all available sources (Ellis, 2000). In this study, diversification levels of income of household calculated by using the inverse Simpson Diversity Index (SDI) (Illukpitiya and Yanagida, 2010):

$$\text{SDI} = 1 - \sum_{i=1}^{N} p_i^2$$

In the survey people recorded a number of different income sources N from which they generated income Pi.

$$\sum_{i=1}^{N} p_i^2 = \left(\frac{I_1}{I_T}\right)^2 + \left(\frac{I_2}{I_T}\right)^2 + \left(\frac{I_3}{I_T}\right)^2 + \left(\frac{I_4}{I_T}\right)^2 + \left(\frac{I_5}{I_T}\right)^2$$

Total value (subsistence and cash) of products from crop production (I_1), livestock products (I_2), NTFPs (I_3), off-farm activity (I_4) and remittance (I_5) then sums up to total household income (IT).

Where, Pi as the proportion of income coming from source i. The value of SDI always falls between zero and one. If there is just one source of income, Pi= one, so SDI=zero. As the number of sources increase, the shares (Pi) decline, as does the sum of the squared shares, so that SDI approaches to one. If there are k sources of income, then SDI falls between zero and 1-1/k accordingly, households with most diversified incomes have the largest SID, and the less diversified incomes are associated with the smallest SDI (Saha and Bahal, 2010).

3.4.3. Estimation of relative forest incomes

Forest income was calculated by estimating the total volume of all types of forest products collected by a household and multiplied by the local market price of each of the products per unit volume. Relative Forest Incomes (RFI) calculated as the proportion of total income originating from forest use and with total household income. It is measure the forest dependence (Vedeld *et al.*, 2004).

$$RFI = \frac{TFI}{THI} * 100$$

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. The socio-economic data were analyzed using both descriptive and inferential statistics to describe the household's characteristics of the respondents, chi-square that were used to compare proportions; t-test were used to compare household incomes diversification, forest products incomes, forest products utilization and status of forest and socioeconomic benefit differences of respondents levels from the natural forest and coffee agroforestry.

4. RESULTS AND DISCUSSION

4.1. Woody Species Composition and Diversity

4.1.1. Species accumulation curve and composition

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 coffee agroforests (Figure 2). This implies that the total number of samples taken for this study were sufficient.

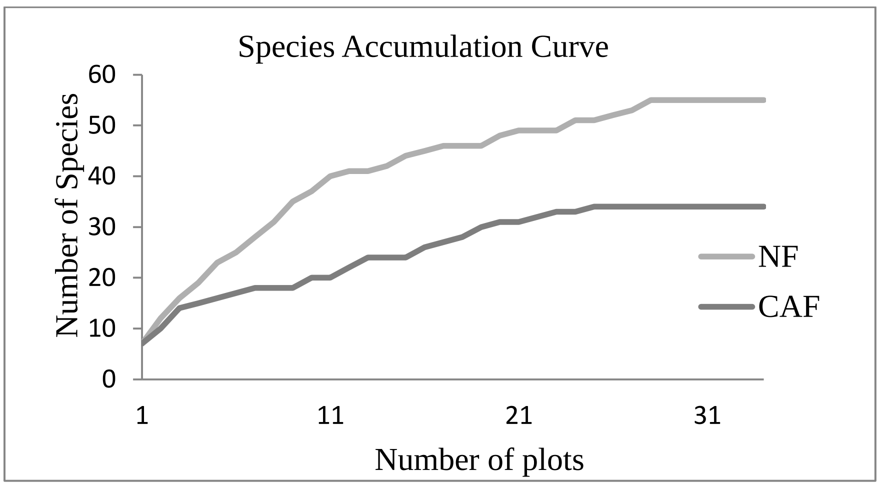

Figure 2: Species accumulation curve of natural forest (NF) and coffee agroforests (CAF)

A total of 67 woody species belonging to 38 families were identified and recorded in the study area, of which 55 belonging to 35 families in natural forest and 33 species belongs to 23 families (Appendix 2 and 3). The most dominated families in natural forest were Fabaceae and Oleaceae both contributing 7.3% of the species recorded, followed by Celasteraceae and Rutaceae each contributing 5.5%. Correspondingly, for coffee agroforests Fabaceae family was the most diverse family having 12.1% of the species (Appendix 4). The family of Fabaceae represented the majority of woody species in both natural forest and coffee agroforests. This study is support by Bajigo and Tadesse (2015) who reported that the family Fabaceae as the dominant family of the woody species recorded in the Wolayitta zone. Fabaceae families were dominant in the southeastern rift valley escarpment of Ethiopia (Negash *et al*., 2012). 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 coffee agroforests share high woody species (S_s=47.19%). Twenty-one woody species were common to both natural forest and coffee agroforests (Table 2). The had similarity in woody species composition between natural forest and coffee agroforests revealed that the woody species in the coffee agroforests are established from natural forest by intensifying management on woody species and they had the same species combination and remnants of the past forest. This finding supported by Molla and Asfaw (2014) shows that (58.67%) of woody species composition similarity existed between natural forest patches and enset based coffee agroforestry.

Table 2: Common woody species for both natural forest and coffee agroforests

Scientific Name	Family
Allophylus abyssinicus	Sapindaceae
Bersema abyssinica	Melianthaceae
*Clausenia anisat*a	Rutaceae
Clerodendron myricoides	Lamiaceae
Cordia africana	Boraginaceae
Croton macrostachyus	Euphorbiaceae
Diosporyus abysssinica	Ebenaceae
Ehretia cymosa	Boraginaceae
Ekebegia capensis	Meliaceae
Fagaropsis angolensis	Rutaceae
Ficus sycomorus	Moraceae
Millettia ferruginea	Fabaceae
Olea capensis	Oleaceae
Phoenix reclinata	Arecaceae
Polyscias fulva	Araliaceae
Prunus africana	Rosaceae
Rhamnus prinoides	Rhamnaceae
Sapium ellipticum	Euphorbiaceae
Syzygium guineense	Myrtaceae
Vernonia amygdalina	Asteraceae
Vernonia auriculifera	Asteraceae

The woody species recorded in natural forest were 52.9 % (224) trees and 31.4% (136) shrubs with few lianas 15.7% (64), whereas in coffee agroforests 72.6% (180) were tree, 25.5% (122) shrubs and 1.6% (6) lianas (Figure 3). The number of woody species varied considerably in the sites under consideration; the tree and lianas were significantly high in natural forest than coffee agroforests ($p < 0.05$). The shrubs had no significant difference between natural forest and coffee agroforests ($p > 0.305$). This variation is due to continuous clearing of the undergrowth vegetation for coffee management, which had caused reduction in woody species in the coffee agroforests.

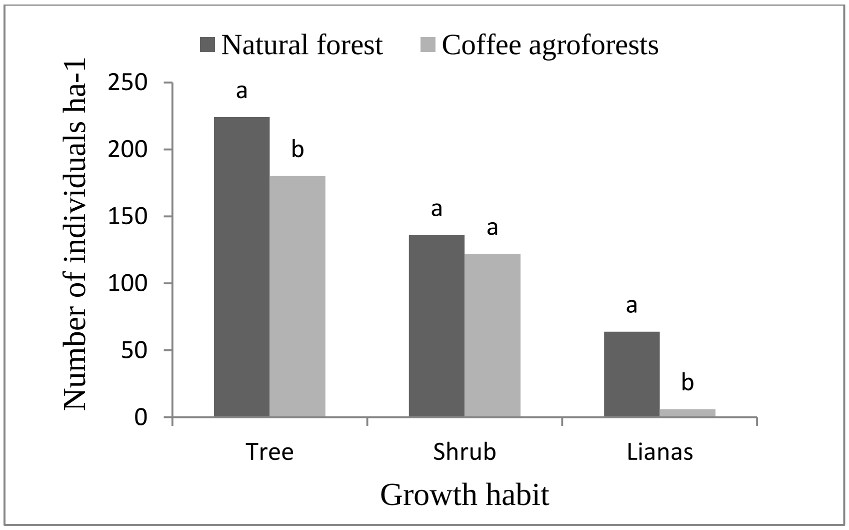

Figure 3: Growth habit of woody species in natural forest and coffee agroforests

4.1.2. Wood species diversity

In natural forest, 55 woody specie were recorded where as in coffee agroforests only 33 different woody species were recorded (Table 3). Although the result shows more woody species under natural forest compared to coffee agroforests, statistical not significantc difference ($p > 0.05$). This study is supported by Tadesse *et al.* (2014) recorded 44 woody species in natural forest and 27 woody species in semi-forest of coffee in south west of Ethiopia. According to Molla and Asfaw (2014), 43 different woody species were recorded in natural forest whereas 32 woody species were recorded in the enset based coffee agroforestry in the Midland of Sidama Zone in Ethiopia. Shannon's diversity index of woody species in natural forest (H' = 3.79) and coffee agroforests with coffee (H'= 2.83). However, the difference in Shannon diversity of woody species was not statistically significant difference ($P > 0.05$) between the natural forest and coffee agroforests (Table 3). Although Shannon diversity index of woody species without coffee in coffee agroforests (H'= 2.54), howerver statistically not significant difference (P > 0.826) between the natural forest and coffee agroforests. This could be the uniform distribution of species in coffee agroforests and enriched by the farmers with economically important species that meet the needs of the local people in coffee agroforests.

Table 3: Diversity of woody species in natural forest and coffee agroforests

Forest site	Richness	Diversity	
		Shannon index	Evenness
Natural Forest	55	3.79	0.95
Coffee agroforests	33	2.83	0.81
p-value	0.134	0.826	0.50

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 support by Boakye *et al*. (2012) who reported that higher diversity index in Ghana natural forests than Taungya agroforests. 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 coffee agroforests were 0.95 and 0.81 respectively. No differences were observed in evenness of species in both natural forests and coffee agroforests. This study supported by Molla and Asfaw (2014) who reported that Shannon eveness of woody species was no significant difference observed between natural forest and enset based coffee agroforestry.

4.1.3. Importance value index

Importance Value Index (IVI) is an important parameter that indicates the ecological significance of species in a given ecosystem (Worku *et al*., 2012). 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 coffee agroforests were listed in Appendix 5 and 6. Accordingly, the ten leading dominant and ecologically important woody species in natural forest and coffee agroforests were given in descending order in Table 4. The species with the highest IVI were *Syzygium guineense* (20.03%), *Croton macrostachyus* (13.59%), *and Maytenus arbutiolia* (13.42%) followed by other species in natural forest. Whereas in coffee agroforests, highest IVIs were *Coffea arabica* (30.90%), *Millettia ferruginea* (29.60%) and *Albizia gummifera* (21.07%) 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.

Table 4: Importance value index of woody species in natural forest and coffee agroforests

Natural Forest		**Coffee agroforests**	
Botanical Name	IVI	Botanical Name	IVI
Syzygium guineense	20.03	*Coffea arabica*	30.90
Croton macrostachyus	13.59	*Millettia ferruginea*	29.60
Maytenus arbutiolia	13.42	*Albizia gummifera*	21.07
Olea capensis	13.19	*Ficus sycomorus*	18.71
Celtis africana	12.86	*Ficus vasta*	18.69
Pittosporum viridiflorum	12.29	*Cordia africana*	18.50
Teclea nobilis	11.34	*Bersema abyssinica*	16.06
Pouteria adolfi-friederici	10.05	*Ehretia cymosa*	15.07
Flacourtia indica	9.51	*Sapium ellipticum*	13.86
Ehretia cymosa	9.47	*Syzygium guineense*	12.36

The high IVI value of species is mainly due to their high dominance, which may be due to their demand by the local people for different purposes. Species with high IVI values regarded as more important and those with low IVI values (Zegeye *et al*., 2011). Therefore, the IVI values can be used to species conservation and species with high IVI value need less conservation efforts, whereas those having low IVI value need high conservation effort. 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).

4.1.4. Population structure

Distribution of all individuals in different DBH size classes in the natural forest and coffee agroforests showed more or less inverted J-shape, there were greater numbers of individuals in the lower diameter size class. In natural forest, 54.35% and coffee agroforests 50.40 % of individuals were concentrated in the first lower diameter size class. Only 1.36% in natural forest and 1.18% in coffee agroforests 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.

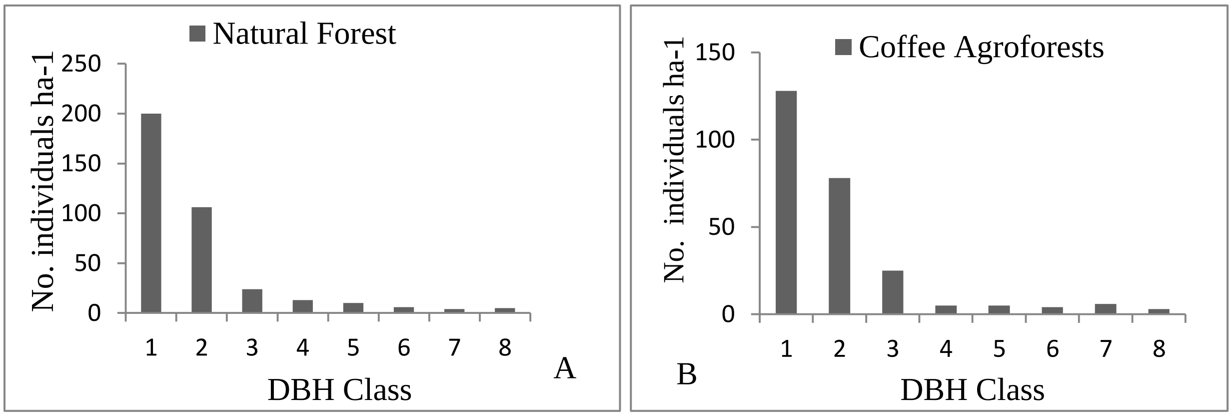

Figure 4: Diameter class distributions of woody species in natural forest (A) and coffee agroforests (B) DBH class: 1 = 10-20 cm; 2 = 20-30 cm; 3 = 30-40 cm; 4 = 40-50 cm and 5 = 50-60 cm; 6=50-60 cm; 7=60-70 cm; and 8 = >80 cm.

Some of woody species density distribution of diameter classes of woody species resulted in different patterns in both natural forest and coffee agroforests (Figure 5). The highest DBH of trees in natural forest > 90 cm was contributed by *Pouteria adolfi-friederici* and in coffee agroforests highest DBH >100 cm were recorded by *Ficus sycomorus* species. The overall structure of the natural forests and coffee agroforests 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.

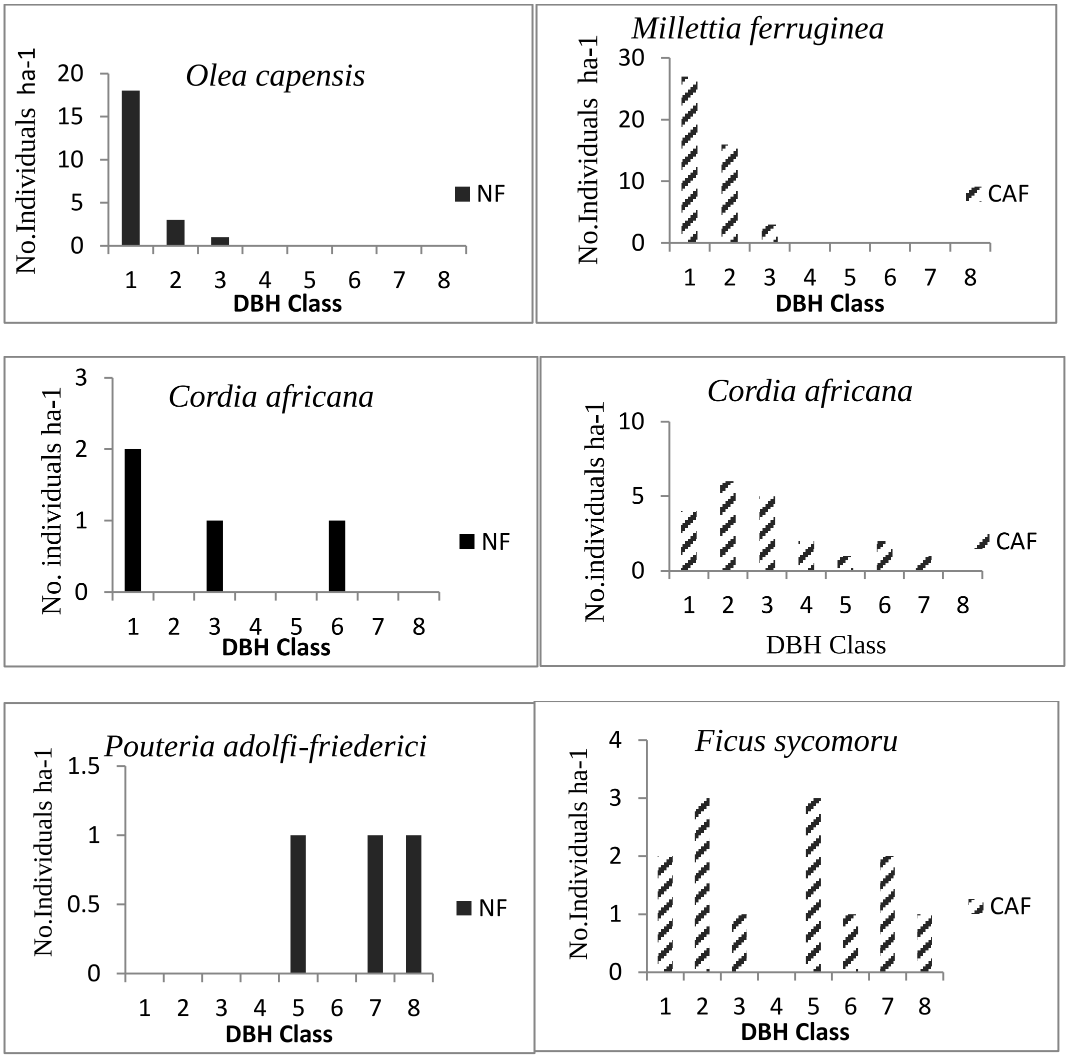

Figure 5: Some of species DBH class in natural forest and coffee agroforests

4.1.5. Regeneration status

The present study showed that the natural forests had higher density of seedling and sapling than coffee agroforests. 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 coffee agroforests (Table 5). This indicated that natural forests have higher regeneration status than coffee agroforests. However, the mean density of tree in natural forest and coffee agroforests show no statistically difference ($p > 0.05$). When the natural forests are converted into coffee agroforests regeneration of woody species decreased. Traditional coffee management system for coffee production is opening up undisturbed forest by clearing undergrowth vegetation competing with coffee and cutting some shade 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 coffee agroforests. This study is supported by Tadesse *et al*. (2014) reported that natural forest fragments have higher regeneration and recruitment than the semi-forest and semi-plantation coffee of the smallholder farmers. This study is also agreed with (Senbeta and Denich, 2006; Hylander *et al*., 2013) who reported that intensive wild coffee management in forest-fragments would reduce density, regeneration of species.

Table 5: Density of seedling, sapling and tree of natural forest and coffee agroforests

Growth Stages	Natural Forest	Coffee Agroforests	P-value
	Density ha-1	Density ha-1	
Seedling	1950.24	1448.02	0.038
Sapling	579.75	424.25	0.034
Tree	458.14	424.21	0.207

Based on the regeneration status of the woody species occurring in the natural forest and coffee agroforests, some of representative of woody species of seedling, sapling and tree/shrub status were recorded (Figure 6). Accordingly, four patterns were observed for regeneration patterns of the woody species in the natural forest and coffee agroforests (Appendix 7). They are:

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

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

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

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

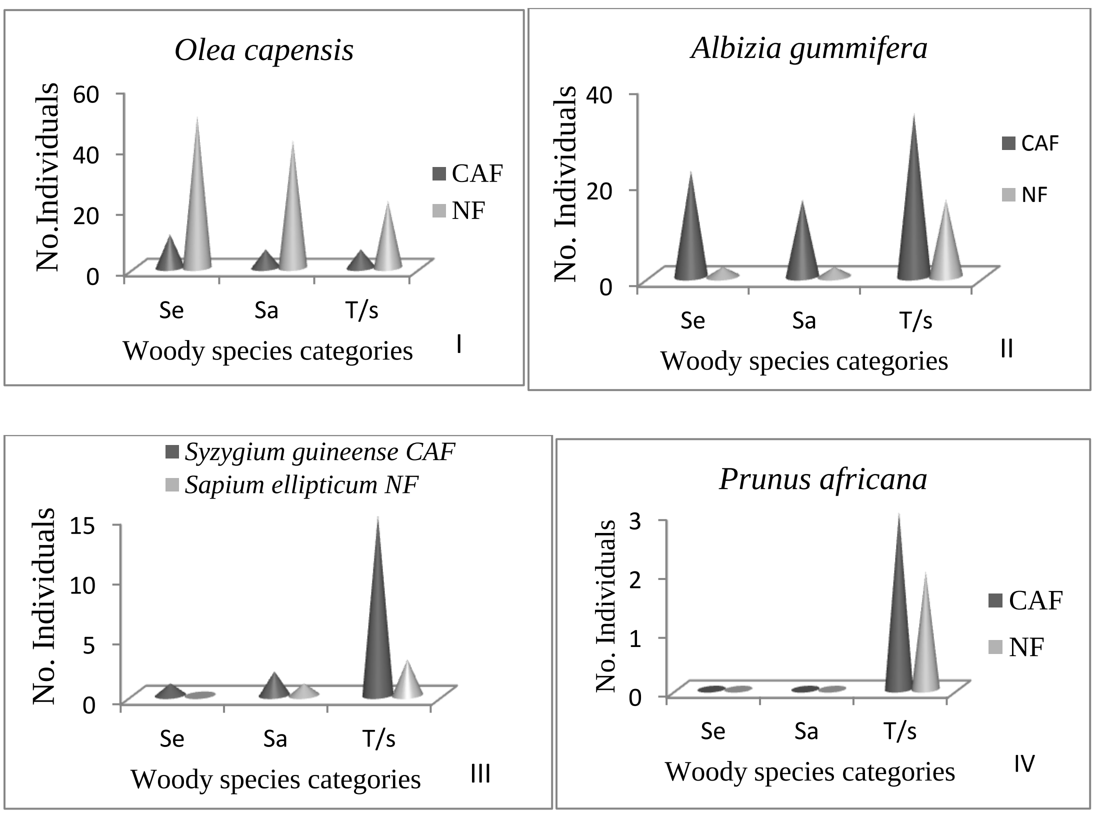

Figure 6: Regeneration status of woody species in natural forest and coffee agroforests

4.2. Socio-economic Benefits

4.2.1. Diversity of forest products

Different categories of forest products were used by household need such as honey, spices, lianas, medicinal plants, charcoal, fuel wood, construction materials and coffee. Households use these products as sources of different purposes and income generation. Diversity of forest product obtained from natural forest and coffee agroforestry were 4.16 and 4.18, respectively (Table 6). However, forest products obtained from both sites were not statistically significant ($P > 0.05$).

Table 6: Forest products obtained from natural forest and coffee agroforestry

Study Area	Diversity of FP
Natural forest	4.16
Coffee agroforestry	4.18
P-value	0.799

FP= Forest Products

The forest is major source of their livelihood and subsistence by providing them a variety of NTFPs. This finding agree with the study conducted by Sutcliffe (2012), in the Masha and Andracha Woreda who demonstrated that forest products those mainly contributed to household income generation and household consumption comprise diverse forest products forest honey, medicinal plants and wild coffee which are collected by local people.

4.2.2. Contribution of Non-timber forest products to household incomes

Depending on socioeconomic benefit of the households, NTFPs play an important role for subsistence and mostly for income generation. NTFPs were used directly to meet household needs for food, construction, medicine, tools and household equipment. As small number of NTFPs (mainly coffee, honey and to lesser extent spices) are sold and contribute significantly to household incomes in the study area. The collection and sale of different NTFPs in the natural forest and coffee agroforestry are shown in Table 7.

Table 7: Contribution of NTFPs for household incomes

	NF		CAF		
NTFPs	Mean incomes	SE	Mean incomes	SE	P-value
Coffee	960.88	228.21	7766.47	684.57	0.00
Honey	560.29	116.47	911.03	124.90	0.19
Spices	29.12	8.10	68.82	23.89	0.02
Lianas	12.94	6.01	0.00	0.00	0.00
Charcoal	30.59	10.20	0.00	0.00	0.00

NF=Natural forest SE= standard error of mean CAF=Coffee agroforestry

Coffee is the major commercial NTFP in the study area. In the natural forest, the sample households were involved in the collection and sale of coffee with a mean annual income of 960.88 ETB. In contrast, in the coffee agroforestry households respondents were involved in the collection and sale of coffee with a mean annual income of 7766.47 ETB. The collection and sell of coffee in both natural forest and coffee agroforestry were significantly different (F=37.631, P <0.01).

Next to coffee, honey is the major NTFPs in the study area. In the natural forest, around 30.9 % of the respondents were involved in the collection and sale of honey with a mean income of 560.29 ETB per year. Although about 31.36 % of the respondents were involved in honey production providing them with a mean annual income of 911.03 ETB in coffee agroforestry there is no statically significant difference in the annual income of honey (F=1.673, P=0.19) in both natural forest and coffee agroforestry.

In addition to coffee and honey, several other NTFPs are also collected. Spices (*Aframomum corrorima* and *Piper capensis*) are the most important amongst NTFPs. 22.06 % in natural forest and 11.02% in the coffee agroforestry were involved in the collection and sale of spices with mean income of household 29.12 and 68.82 ETB per year. There were significance difference between mean annual income of spices between natural forest and coffee agroforesry (F=10.198, P=0.02). Relatively only 7.35% respondent households were involved in natural forest in the production and sale of charcoal with a mean income of 30.59 ETB per year and 14.71% the respondents were involved in the collection and sale of lianas with a mean income of 12.94 ETB per year.

In this study, mean annual income NTFPs for household respondents for both natural forest and coffee agroforestry were 2402 ETB and 10765 ETB respectively showed different level of income (Table 8). The contributions of NTFP to household income of coffee agroforestry were significantly higher than household income of natural forest. These implies that households income level of coffee agroforestry are remarkably more engaged in the collection and sale of NTFPs, which reflected, by their significantly higher amount of cash income from NTFPs compared to that of the natural forest.

Table 8: NTFPs income of natural forest and coffee agroforestry

Study Site	Income of NTFP (ETB)	RFI
NF	2402	11
CAF	10765	49
p-value	<0.0001	<0.0001

RFI= Relative Forest, Income NF=Natural forest, CAF=Coffee agroforestry

While relative contribution of forest income in natural forest households were (11%) whereas the contribution of relative forest income for coffee agroforestry were (49%). The relative importance of forest income varied significantly ($P < 0.05$) across natural forest and coffee agroforestry. This data regarding the greater livelihood role of coffee agroforestry systems compared to the natural forest with a much higher forest cover, adds to the growing evidence that the highest potential for NTFPs production are not situated in forest areas, but relatively in coffee agroforestry. Such coffee agroforestry offer good opportunities for incorporating NTFPs production in household diversification strategies within the setting of a multi-enterprise livelihood system. The findings demonstrated that local people collect different NTFPs for income generation and households' consumption for their livelihood. The contribution of forest products to rural communities was studied in different areas, which showed the contribution of NTFPS to household income is vital. This study agree with the findings of Adilo (2007) who reported that major sources of cash income for households, were NTFPs, such as forest coffee, honey and spices. This present study is supported by Demek *et al.* (2014) who reported that the NTFPs, forest coffee contributed most of household incomes at 64%, followed by honey (24%) and spices (12%). Coffee agroforestry incomes increased when households derive their main income from NTFPs (coffee and honey). Increased production of NTFPs might be achieved through human intervention and such intervention may range from enriching forests with valuable NTFPs species to cultivation of NTFPs species in agroforestry systems. The value of NTFPs in such anthropogenic vegetation types is higher than that of undisturbed natural forests (Ros-Tonen and Wiersum, 2005).

4.2.3. Diversification of households incomes

The Simpsons Diversification Index (SDI) is affected both by the number of income sources as well as by the distribution of income between different sources. Mean degrees of diversification of natural forest were 0.16 SDI, household are more specialized livelihood and predominantly engaged in crop and livestock production, and possibly combined with some NTFPs they earn a low income (Table 9). This indicates that a specialization implies the household income low.The low observed degree of income diversification in natural forest shows that the households in the natural forest less diversified in relation to the income generating activities. This study agree with (Agyeman *et al*., 2014) degree of diversification of low observed degree of income diversification 0.338 SID shows that farm households in the Western Region of Ghana are less diversified in relation to the income generating activities. Thus, farm households tend to concentrate their sources of income in few activities especially farming related ones.

Table 9: Diversification of the household incomes of natural forest and coffee agroforestry

Study Area	SDI
Natural forest	0.16
Coffee agroforestry	0.45
P-value	0.000

SDI= Simpsons Diversification Index,

In the coffee agroforestry, 0.45 SDI obtained highest incomes and show more diversified compared to natural forest. The relatively high degrees of diversification recorded in coffee agroforestry households obtain attributed to the NTFPs such as coffee and honey and agricultural products especially crops, which fetch relatively higher income than natural forest area.The reason might be that the production of commercial NTFPs (coffee and honey), crop and livestock production. This showed the good potential of a diversified livelihood with high value NTFPs production enhancing agricultural production. This study agrees with that of Babatunde and Qaim (2009) who reported that 0.479 patterns of income diversification fairly diversified income among household sources in rural Nigeria. This finding supported by Rice (2008), who reported that shaded agroforestry vital role in diversifying farming systems by producing fruits and non-timber forest products NTFPs. This study also supported by (Reddy *et al*., 2004) the smallholder coffee producers obtain supplementary advantages from diversification farming method to promote the household economy.

4.2.4. Forest product utilization and access

The livelihood of the study area largely depends on timber and non-timber forest products. In the case of natural forest, 36.8% of the household respondents' explaned that they access uses of timber in the natural forest area restricted (Figure 7). However, about 63.2% of the household respondents responded that access to use timber in natural forest is common. In contrast, in coffee agroforestry all of the respondents report that access to use timbers highly restricted. Because the coffee agroforests was managed and protected by the owner and no one can enter and use the timber where as in natural forest it open access everyone was using the timber products. In addition, the household respondents of coffee agroforestry can get dead branches or wood from their own farms for their fuel wood and lumber needs. Most households look forward to harvesting NTFPs and timber from their owned land and a considerable increase in their cash income from coffee agroforestry. Therefore, the household of coffee agroforestry decrease their dependence from the natural forests.

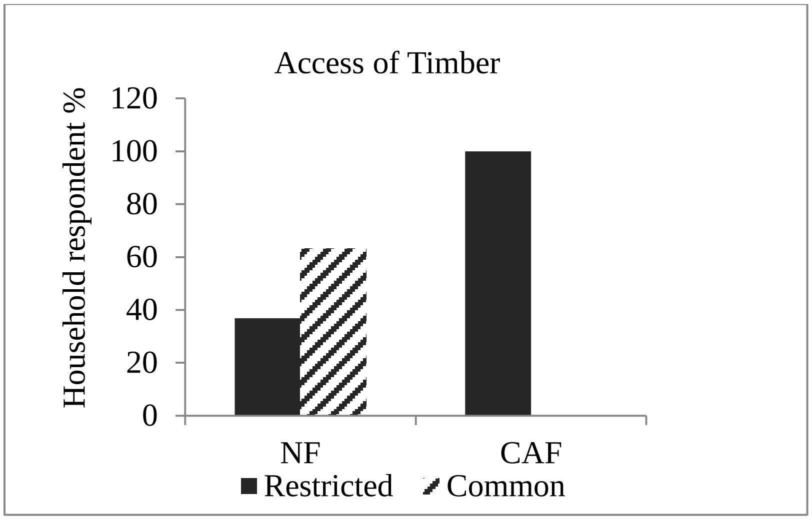

Figure 7: Access of timber in natural forest and coffee agroforestry

In the natural forest, 94.1% of household respondents use the NTFPs as common from the forest where as 5.9% 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 coffee agroforestry, access to use NTFPs high restricted around 89.7% of household respondents reported that no one could use NTFPs in the area because of their property (Figure 8). However, 10.3% of the household respondents stated that they have access to collect NTFPs in coffee agroforestry. They were allowed to collect some of NTFPs products such as fuel wood and medicinal plants after the coffee harvested. Accordingly, coffee agroforestry under the ownership of farmers have existed so far mainly because of the way they have been cultivating coffee with a management for the most of the time restricted because clearing of undergrowth before collection of coffee berries.

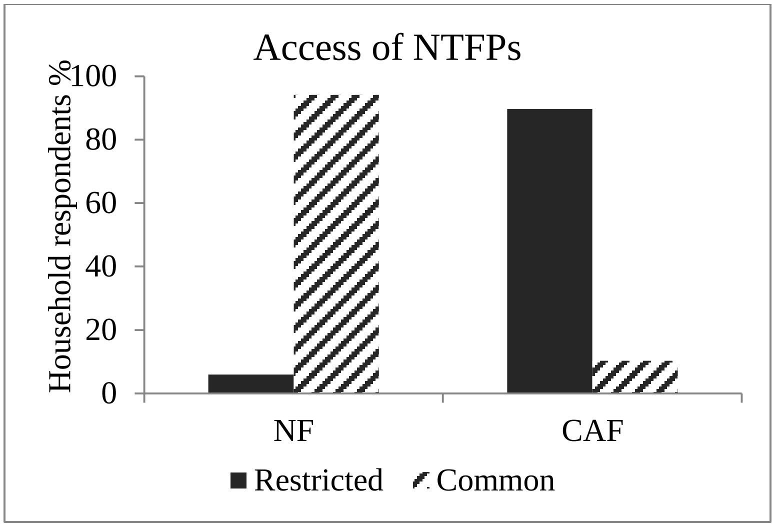

Figure 8: Access of NTFPs in natural forest and coffee agroforestry

Forest resources in the natural forest are accessible to any community member thereby leading to the forest resource being open to extraction to anyone. The forest resources that are open to extraction forest products. Generally, most households in the natural forest depend on accessing forest resources for their day-to-day use. Households located within Ethiopia forest-farm interface tend to be highly dependent upon forest resources for fuel wood, livestock grazing and building materials (Mamo *et al*., 2007). The result is supported by Dayal (2006) who reported that forest product extraction and the extent of natural resource degradation is often attributed to rapid population growth and open access nature of those resources, especially forests. Recently, however, the uses of forest services have been diminished in southwest Ethiopia due to lack of ownership and local access to the use of forests following land-tenure changes (Tadesse *et al*., 2013).

4.2.5. Status of forest area

The result of the study revealed that 89.7% of the respondents perceived the existing natural forest as decreasing, whereas 5.9% of the respondents perceived as no change. However, 4.4% household respondents said forest areas increasing. The main causes for the depletion of forests area due to agricultural expansions, illegal settlement to the forest and road construction in the natural forests area (Figure 9).

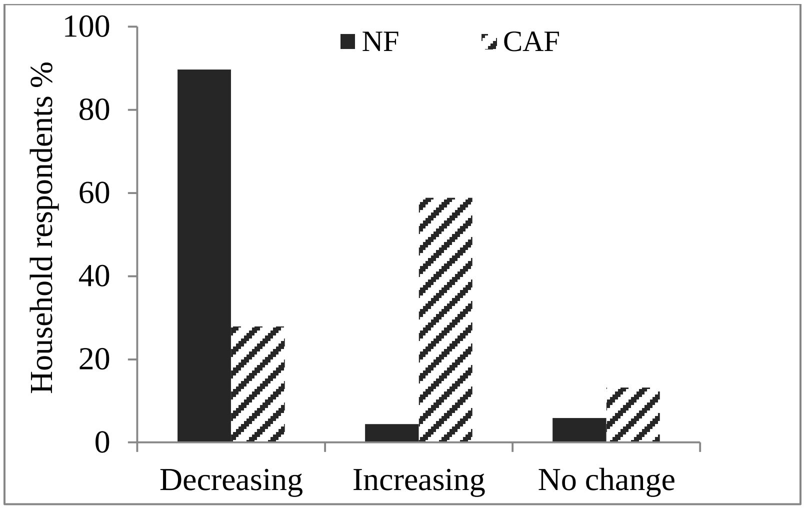

Figure 9: Status of forest area in natural forest and coffee agroforestry

In the coffee agroforestry, forest area is increasing 58.8% of the respondents, whereas 13.2% of the respondents responded that forest area was no change. In contrast the about 27.9% of the respondent report that forest area decreasing. The main reasons of coffee agroforestry 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 conversed into agricultural land. The farmers used to get different functions and services from the forest such as firewood, medicine, bee keeping, house construction materials, food, etc. 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 deforestation in the study area were expansion of agricultural land, fuel wood collection, charcoal making, land use change by investors and settlements of people, in descending order of severity.

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 parts of the country, the forest areas in this region are declining rapidly, primarily due to the conversion of forests into agricultural land (Bekele, 2003).

4.2.6. Status of species composition

Response from household respondents revealed that 82.4% and 92.6 % of the respondents supposed the species composition of natural forest and coffee agroforestry highly decreasing. Whereas 2.9% and 7.4% respondents reported that species compositions of natural forest and coffee agroforestry were increasing (Figure 10). However about 14.7% of the respondents stated that the species composition of natural forest was no change. 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.

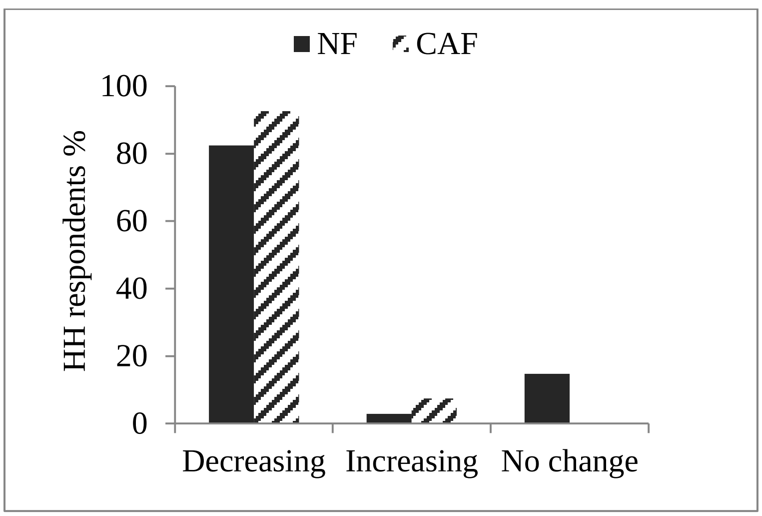

Figure 10: Status of species composition in natural forest and coffee agroforestry

The result has indicated that expansion of coffee management is the most important cause of species destruction followed by fuel wood and cutting tree for farm tools. 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. The major reasons of decreasing forest species are clearing of forests for cultivating crops and cutting of trees and shrubs for various purposes, notably for fuel wood, farm tools, charcoal, construction material, timber, etc. In both natural forest and coffee agroforestry, 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) showed 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). This result is support by Hylander *et al*. (2013) described that smallholder farms particularly, and state-owned plantations to a lesser extent, have great conservation potential besides reducing overexploitation of forest species for fuel wood, charcoal and construction.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Belete forest has a vast ecological and economic importance, but due to human induced factors, there is a persistently high rate of biodiversity loss. There is need of biodiversity conservation. The results of the present study confirm that natural forest and coffee agroforests constitutes larger proportion of woody species, which may be a reflection of conservation of biodiversity. Coffee agroforests is conserving woody species by doing management practice in maintaining more species as shade of coffee and economically useful species. Although providing different forest products to farmers. This implies that coffee agroforests indirectly contribute to the conservation of biodiversity through reducing pressure that would be exerted on natural forests, so coffee agroforests provide as a buffer zone in natural forest conservation.

The study compared a consistent set of description of the characteristics of the forest product and diversification strategy. In the natural forest, household incomes shows specialized because more engaged in agricultural practise. However, in coffee agroforestry shows that household income diversified with high value product and engaged in different activities. Different ways to address dependence on forest products incomes, in case of natural forest, the relationship between diversification and relative forest incomes indicates that specialization. Therefore, dependence on agricultural and other incomes simply represents the utilization of the additional income opportunities that the forests provide less. Yet, coffee agroforestry, the relationship between diversification and relative forest incomes implies that diversified and increasing with forest income. Therefore, coffee agroforestry provide different forest product incomes and reduce dependence from natural forest.

5.2. Recommendation

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

- Conservation practitioners and policy makers seeking to promote coffee agroforestry as woody species conservation under sound management guidelines that dictates use and conservation forest resources
- Conservation of woody species and socioeconomic benefits must be linked in the arena of conservation approaches
- Further studies would be required on advanced regeneration species with no regeneration as it disappears in future

6. REFERENCES

Adilo, M. 2007. The contribution of non-timber forest products to rural livelihood in Southwest Ethiopia. MSc Thesis. Wageningen: Wageningen University.

Aerts, R., Hundera, K., Berecha, G., Gijbels, P., Baeten, M., Mechelen, M.V., Hermy, M., Muys, B., and Honnay, O. 2011. Semi-forest coffee cultivation and the conservation of Ethiopian Afromontane rainforest fragments. *Forest Ecology and Management*, **261(6)**:1034–1041.

Babatunde, R. O., and Qaim, M. 2009. Patterns of income diversification in rural Nigeria: determinants and impacts. *Quarterly Journal of International Agriculture*, **48(4)**:305-320.

Bacon, C. M., Méndez, V. E., and Fox, J. A. 2008. Cultivating sustainable coffee: persistent paradoxes. Confronting the Coffee Crisis: Fair Trade, Sustainable Livelihoods and Ecosystems in Mexico and Central America. *MIT Press*, *Cambridge*, *MA*, 337-372.

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

Barlett, J.E., Kotrlik, J.W. and Higgins, C.C. 2001. Organizational research: Determining appropriate sample size in survey research. *Information Technology*, *Learning*, *and Performance Journal*, **19(1)**:43.

Bekele, M. 2003. Forest property rights, the role of the state and institutional exigency: The Ethiopian case. [PhD thesis]. Uppsala, Sweden: Swedish University of Agricultural Sciences.

Bekele, M., Tesfaye, Y., Mohammed, Z., Zewdie, S., Tebikew, Y., Brockhaus, M. and Kassa, H. 2015. The context of REDD+ in Ethiopia: Drivers, agents and institutions. Occasional Paper 127. Bogor, Indonesia: *Center for International Forestry Research.*

Bekele-Tesemma, A. 2007. Useful trees and shrubs of Ethiopia: identification, propagation and management for 17 agro-climatic zones; Technical manual number 6. *World agro-forestry center*.

Belcher, B., Ruiz-Perez, M. and Achdiawan, R. 2005. Global patterns and trends in the use and management of commercial NTFPs: Implications for livelihoods and conservation. W*orld Development,* **33(9)**: 1435–1452.

Bhagwat, S.A., Willis, K.J., Birks, H.J.B. and Whittaker, R.J. 2008. Agroforestry: a refuge for tropical biodiversity? *Trends in ecology and evolution*, **23(5)**:261-267.

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.

Bond, W.J. and Parr, C.L. 2010. Beyond the forest edge: Ecology, diversity and conservation of the grassy biome. *Biological Conservation*, **143**:2395-2404.

Buechley, E.R., Sekercioglu, Ç.H., Atickem, A., Gebremichael, G., Ndungu, J.K., Mahamued, B.A., Beyene, T., Mekonnen, T. and Lens, L. 2015. Importance of Ethiopian shade coffee farms for forest bird conservation. *Biological Conservation*, **188**:50-60.

Buscher, B. and Whande, W., 2007. Whims of the winds of time? Emerging trends in biodiversity conservation and protected area management. *Conservation and Society*, ***5*****(1)**:22.

Chazdon, R.L., Harvey, C.A., Komar, O., Griffith, D.M., Ferguson, B.G., Martínez-Ramos, M., Morales, H., Nigh, R., Soto-Pinto, L., Van Breugel, M. and Philpott, S.M. 2009. Beyond reserves: A research agenda for conserving biodiversity in human-modified tropical landscapes. *Biotropica*, **41(2)**:142-153.

Cheng, S., Hiwatashi, Y., Imai, H., Naito, M. and Numata, T. 1998. Deforestation and degradation of natural resources in Ethiopia: Forest management implications from a case study in the Belete-Gera Forest. *Journal of Forestry Research*, **3**:199-204.

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

Dawson, I.K., Guariguata, M.R., Loo, J., Weber, J.C., Lengkeek, A., Bush, D., Cornelius, J., Guarino, L., Kindt, R., Orwa, C. and Russell, J. 2013. What is the relevance of smallholders' agroforestry systems for conserving tropical tree species and genetic diversity in circa situm, in situ and ex situ settings? A review. *Biodiversity and Conservation*, **22(2)**:301-324.

Dayal, V. 2006. A micro econometric analysis of household extraction of forest biomass goods in Ranthambhore National Park, India. *Journal of Forest Economics*, **12**: 145-163.

De Beenhouwer, M., Aerts, R. and Honnay, O. 2013. A global meta-analysis of the biodiversity and ecosystem service benefits of coffee and cacao agroforestry. *Agriculture, ecosystems and environment*, **175**:1-7.

DeFries, R.S., Rudel, T., Uriarte, M. and Hansen, M. 2010. Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience*, **3**:178-181.

Demissew, S., Cribb, P. and Rasmussen, F. 2004. Field guide to Ethiopian orchids. Royal Botanic Gardens, Kew, UK. 300 pp.

Dewi, S., Belcher, B. and Puntodewo, A. 2005. Village Economic Opportunity, Forest Dependence, and Rural Livelihoods in East Kalimantan, Indonesia. *World Development*, **33(9)**:1419–1434.

Dibaba, A., Soromessa, T., Kelbessa, E. and Tilahun, A. 2014. Diversity, Structure and Regeneration Status of the Woodland and Riverine Vegetation of Sire Beggo in Gololcha District, Eastern Ethiopia. *Momona Ethiopian Journal of Science*, **6(1)**:70-96.

Didita, M., Nemomissa, S. and Woldemariam, T. 2010. Floristic and structural analysis of the woodland vegetation around Dello Menna, Southeast Ethiopia. *Journal of Forestry Research*, **21**: 395-408.

Drozd, P. and Novotny, V., 2010. AccuCurve, MS Excel Macro–Version 1.

Duguma, LA. and Hager, H. 2009. Forest products scarcity perception and response by tree planting in the rural landscapes: farmers' views in central highlands of Ethiopia. *Ekológia (Bratislava),* **28(2)**:158-169.

Edwards, S., Mesfin, T., Sebsebe, D. and Hedberg. I. (eds.). 2000. Flora of Ethiopia and Eritrea. **2(1)**. The National Herbarium Addis Ababa University, Addis Ababa and Department of Systematic Botany, Uppsala University, Uppsala.

Ellis, F. 2000. The Determinants of Rural Livelihood Diversification in Developing Countries *Journal of Development and Agricultural Economics*, **51(2)**:289-302.

Fisher, B., Turner, R.K. and Morling, P., 2009. Defining and classifying ecosystem services for decision-making. *Ecological economics*, **68(3)**:643-653.

Fjeldsa, J., 2007. How Broad-Scale Studies of Patterns and Processes Can Serve to Guide Conservation Planning in Africa. *Conservation biology*, **21(3)**:659-667.

Foley, J.A., DeFries R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K. and Helkowski, J.H., 2005. Global consequences of land use. *Science*, **309**:570-574.

Gardei, S. 2006. Local valuation of forests in South West Ethiopia. Non timber Forest Products Research and Development Project in SW Ethiopia, Wageningen, Series No. 6. Netherlands.

Gardner, T.A., Barlow, J., Chazdon, R., Ewers, R.M., Harvey, C.A., Peres, C.A. and Sodhi, N.S., 2009. Prospects for tropical forest biodiversity in a human-modified world. *Ecology letters*, **12(6)**:561-582.

Gardner, T.A., Barlow, J., Sodhi, N.S. and Peres, C.A. 2010. A multi-region assessment of tropical forest biodiversity in a human-modified world. *Biological Conservation*, **143(10):**2293-2300.

Geist, H.J. and Lambin, E.F. 2002. Proximate Causes and Underlying Driving Forces of Tropical Deforestation Tropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical location.*Bioscience*, **52(2)**:143 -150.

Gibson, L., Lee, T.M., Koh, L.P., Brook, B.W., Gardner, T.A., Barlow, J., Peres, C.A., Bradshaw, C.J., Laurance, W.F., Lovejoy, T.E. and Sodhi, N.S. 2011. Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature*, **478**:378-381.

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

Gomez-Baggethun, E., Groot, R., Lomas, P. L. and Montes, C. 2010. The history of ecosystem services in economic theory and practice: from early notions to markets and payment schemes. *Ecological Economics*, **69(6):**1209-1218.

Gordon, C., Manson, R., Sundberg, J. and Cruz-Angon, A. 2007. Biodiversity, profitability, and vegetation structure in a Mexican coffee agroecosystems. *Agriculture, ecosystems and environment*, **118(1)**:256-266.

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

Haines-Young, R. 2009. Land use and biodiversity relationships. *Land use policy*, **26:** 178-186.

Harvey, C.A., Komar, O., Chazdon, R., Ferguson, B.G., Finegan, B., Griffith, D.M., Martinez-Ramos, M.L., Morales, H., Nigh, R., and Van Breugel, M. 2008. Integrating agricultural landscapes with biodiversity conservation in the Mesoamerican hotspot. *Conservation biology*, **22(1)**:8-15.

Hedberg, I., Ensermu, K., Edwards, S, Sebsebe, D., and Persson, E. 2006. Flora of Ethiopia and Eritrea, Vol. **5**. The National Herbarium, Addis Ababa.

Hundera, K. and Gadissa, T. 2013. Vegetation composition and structure of the Belete Forest, Jimma Zone, South Western Ethiopia. *Ethiopian Journal of Biological Sciences*, 7(1):1-15.

Hundera, K., Aerts, R., Fontaine, A., Van Mechelen, M., Gijbels, P., Honnay, O., Muys, B. 2013. Effects of coffee management intensity on composition, structure and regeneration of Ethiopian Moist Evergreen Afromontane Forests. *Environmental Management*, **51(3):**801-809.

Hylander, K., Nemomissa, S., Delrue, J. and Enkosa, W. 2013. Effects of coffee management on deforestation rates and forest integrity. *Conservation Biology*, **27(5)**:1031-1040.

Illukpitiya, P. and Yanagida, J.F. 2010. Farming vs. forests: trade-off between agriculture and the extraction of non-timber forest products. *Ecological Economics*, **69**:1952–1963.

Jha, S., Bacon, C.M., Philpott, S.M., Mendez, V.E., Laderach, P. and Rice, R.A. 2014. Shade coffee: update on a disappearing refuge for biodiversity. *BioScience*, **64(5)**:416-428.

JICA, 2010. Report of the terminal evaluation on the Japanese technical cooperation for the participatory forest management project in Belete-Gera regional forest priority area, phase 2 in the Federal Democratic Republic of Ethiopia. Japan International Cooperation Agency.

Kelbessa, E. and Soromessa, T. 2008. Interfaces of Regeneration, Structure, Diversity and Uses of Some Plant Species in Bonga Forest: A Reservoir for Wild Coffee Gene Pool. *Ethiopian Journal* of *Sciences*, **31(2)**:121–134.

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

Komar, O. 2006. Priority Contribution. Ecology and conservation of birds in coffee plantations: a critical review. *Bird Conservation International*, **16(01)**:1-23.

Labouisse, J., Ballachew, B., Kotecha, S. and Bertrand, B. 2008. Current status of coffee (Coffea arabica L.) genetic resources in Ethiopia: implications for conservation. *Genetic Resources and Crop Evolution*, **55**:1079–1093.

Leadley, P. 2010. Biodiversity scenarios: projections of 21st century change in biodiversity, and associated ecosystem services: a technical report for the global biodiversity outlook 3 (No. 50). UNEP/Earth print.

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.

Lindenmayer, D. and Hunter, M. 2010. Some Guiding Concepts for Conservation Biology. *Conservation Biology*, **24(6)**: 1459-1468.

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

Mamo, G., Sjaastad, E. and Vedeld, P. 2007. Economic dependence on forest resources: A case from Dendi district, Ethiopia. *Forest Policy and Economics,* **9**:916–27.

Mas, A.H. and Dietsch, T.V. 2004. Linking shade coffee certification to biodiversity conservation: butterflies and birds in Chiapas, Mexico. *Ecological Applications*, **14(3):** 642-654.

Mayfield, M.M. and Daily, G.C. 2005. Countryside biogeography of Neotropical herbaceous and shrubby plants. *Ecological applications*, **15(2)**:423-439.

Melaku, E., Ewnetu, Z., Teketay, D., 2014. Non-timber forest products and household incomes in Bonga forest area, Southwestern Ethiopia. *Journal of Forestry Research*, **25(1)**: 215-223

Mendez, V.E., Shapiro, E.N. and Gilbert, G.S., 2009. Cooperative management and its effects on shade tree diversity, soil properties and ecosystem services of coffee plantations in western El Salvador. *Agroforestry Systems*, **76(1)**:111-126.

Mendez, VE., Bacon, CM., Olson, M., Morris, KS. and Shattuck, AK. 2010. Agrobiodiversity and shade coffee smallholder livelihoods: a review and synthesis often years of research in Central America. *Professional Geographer,* **62(3)**:357-376.

Moges, Y., Eshetu, Z. and Nune, S. 2010. "Ethiopian Forest Resources: Current Status and Future Management Options in View of Access to Carbon Finances." Addis Ababa, October 2010, Ethiopia: Ethiopian Climate Research and Networking; *the United Nations Development Programme.* 55

Moguel, P. and Toledo, VM. 1999. Biodiversity conservation in traditional coffee systems of Mexico. *Conservation Biology*, **13(1)**:11-21.

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.

Molla, A. and Kewessa, G., 2015.Woody Species Diversity in Traditional Agroforestry Practices of Dellomenna District, Southeastern Ethiopia: Implication for Maintaining Native Woody Species. *International Journal of Biodiversity*, 2015:1-13.

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.

Muleta, D., Assefa, F., Nemomissa, S. and Granhall, U. 2008. Distribution of arbuscular mycorrhizal fungi spores in soils of smallholder agroforestry and monoculture coffee systems in; southwestern Ethiopia. *Biology and fertility of soils*. **44(4)**:653-659.

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

Negash, M., Yirdaw, E. and Luukkanen, O. 2012. Potential of indigenous multistrata agroforests for maintaining native floristic diversity in the south-eastern Rift Valley escarpment, Ethiopia. *Agroforestry systems*, **85(1)**:9-28.

Pereira, H.M., Leadley, P.W., Proença, V., Alkemade, R., Scharlemann, J.P., Fernandez-Manjarres, J.F., Araujo, M.B., Balvanera, P., Biggs, R., Cheung, W.W. and Chini, L. 2010. Scenarios for global biodiversity in the 21st century. *Science*, **330(6010)**:1496-1501.

Perfecto, I., Armbrecht, I., Philpott, S.M., Soto-Pinto, L. and Dietsch, T.V. 2007. Shaded coffee and the stability of rainforest margins in northern Latin America. In *Stability of Tropical Rainforest Margins* (pp. 225-261). Springer Berlin Heidelberg.

Perfecto, I., Rice, R., Greenberg, M. and Van der Voort, M.E. 1996. Shade coffee: a disappearing refuge for biodiversity. *Bioscience*, **46(8)**: 598–608.

Pfund, J.L. 2010. Landscape-scale research for conservation and development in the tropics: Fighting persisting challenges. *Current Opinion in Environmental Sustainability*, **2(1)**:117-126.

Pielou, E. C. 1975. Ecological diversity. John Wiley and Sons, INC, 165.

Power, A.G. 2010. Ecosystem services and agriculture: tradeoffs and synergies. Philosophical Transactions of the Royal Society of London B: *Biological Sciences,* **365**:2959-2971.

Reichhuber, A. and Requate, T. 2012. Alternative use systems for the remaining Ethiopian cloud forest and the role of Arabica coffee a cost-benefit analysis. *Ecological Economics*, **75**:102-113.

Rice, R.A., 2008. Agricultural intensification within agroforestry: the case of coffee and wood products. *Agriculture, ecosystems and environment*, **128(4)**: 212-218.

Rosenzweig, M.L.1995. Species diversity in space and time. Cambridge University Press, Cambridge**.**

Ros-Tonen, M.A.F. and Wiersum, K.F. 2005. The Scope for Improving Rural Livelihoods through Non-Timber Forest Products: An Evolving Research Agenda. *Forests, Trees and Livelihoods*, **15**:129-148.

Sagar, R., Singh, A. and Singh, J.S. 2008. Differential effect of woody plant canopies on species composition and diversity of ground vegetation: a case study. *Tropical Ecology*, **49(2)**: 189-197.

Saha, B. and Bahal, R. 2010. Livelihood Diversification Pursued by Farmers in West Bengal. *Indian Research Journal of Extension Education,* **10(2)**:1-9.

Scherr, S.J. and McNeely, J.A. 2005. Biodiversity conservation and agricultural sustainability: Towards a new paradigm of 'Eco-agriculture' landscapes. *Philosophical Transactions of the Royal Society of London B: Biological Sciences Biological Sciences*, **363**: 477–494.

Schmitt, C.B., Denich, M., Demissew, S., Friis, I. and Boehmer, H.J. 2010. Floristic diversity in fragmented Afromontane rainforests: altitudinal variation and conservation importance. *Applied Vegetation Science*, **13(3)**: 291-304.

Schmitt, C.B., Senbeta, F., Denich, M., Preisinger, H. and Boehmer, H.J. 2009. Wild coffee management and plant diversity in the montane rainforest of Southwestern Ethiopia. *African Journal of Ecology*, **48**:78–86.

Schroth, G., Harvey, CA. and Vincent, G. 2005. Complex agroforests their structure, diversity, and potential role in landscape conservation. In: Schroth G, Fonseca GAB, Harvey CA et al (eds) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington, DC, 227–260.

Senbeta, F. 2006. Biodiversity and ecology of Afromontane rainforests with wild Coffea arabica L. populations in Ethiopia. Dissertation, University of Bonn.

Senbeta, F. and Denich, M. 2006. Effects of wild coffee management on species diversity in the Afromontane rainforests of Ethiopia. *Forest Ecology and Management*, **232(1)**: 68-74.

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

Shackleton, S. and Gumbo, D. 2010. Contribution of non-wood forest products to livelihoods and poverty alleviation. In: Chidumayo, E. N. & Gumbo, D. J. (eds.) the dry forests and woodlands of Africa: managing for products and services. London: Earthscan.

Shekhar, C.S. 2001. Status and distribution of anthropogenic pressure in the buffer zone of Nanda Devi Biosphere Reserve in western Himalaya, India. *Biodiversity and Conservation*, **10**: 1113–1130.

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.

Silvestrini, M., Junqueira, M.G., Favarin, A.C., Guerreiro, O., Maluf, M.P., Silvarolla, M.B. and Colombo, C.A. 2007. Genetic diversity and structure of Ethiopian, Yemen and Brazilian Coffea arabica L.*Genetic Resources and Crop Evolution,* **54:**1367–1379.

Soromessa, T., Teketay, D. and Demissew, S. 2004. Ecological study of the vegetation in Gamo Gofa zone, Southern Ethiopia. *Tropical Ecology*, **45(2)**: 209-221.

Stills, E. Shanley, P., Paumgarten, F., De Beer, J. and Pierce, A. 2012. Evolving perspectives on non-timber forest products. In: Shackleton (eds.) Non-timber forest products in the global context. Tropical Forestry, 7, Springer-Verlag, Berlin Heidelberg.

Sunderland, T., Ehringhaus, C. and Campbell, B. 2008. Conservation and development in tropical forest landscapes: A time to face the trade-offs? *Environmental Conservation*, **34(4)**: 276-279.

Sutcliffe, J., Wood, A. and Meaton, J. 2012. 'Competitive forests making forests sustainable in south-west Ethiopia' *International Journal of Sustainable Development & World Ecology*, **19 (6)**:471-481.

Tadesse, G. 2013. Biodiversity and livelihoods in southwestern Ethiopia: Forest loss and prospects for conservation in shade coffee agroecosystems (Ph.D.dissertation). Santa Cruz, USA: University of California.

Tadesse, G., Zavaleta, E. and Shennan, C. 2014. Coffee landscapes as refugia for native woody biodiversity as forest loss continues in southwest Ethiopia. *Biological Conservation*, **169**: 384-391.

Tesfaye, Y., Roos, A., Campbell, B.M. and Bohlin, F. 2010. Forest Incomes and Poverty Alleviation under Participatory Forest Management in the Bale Highlands, Southern Ethiopia. *International Forestry Review*, **12(1)**: 66-77.

Todo, Y. and Takahashi, R. 2013. Impact of Farmer Field Schools on Agricultural Income and Skills: Evidence from an Aid-Funded Project in Rural Ethiopia. *Journal of International Development*, **25(3)**:362-381.

Tscharntke, T., Clough, Y., Wanger, T.C., Jackson, L., Motzke, I., Perfecto, I., Vandermeer, J. and Whitbread, A. 2012. Global food security, biodiversity conservation and the future of agricultural intensification. *Biological Conservation*, **151(1)**: 53–59.

Vedeld, P., Angelsen, A., Sjaastad, E. and Berg, G.K. 2004. Counting on the environment: forest income and the rural poor. EDP 98. World Bank, Washington D.C., USA.

Winberg, E. 2010.Participatory forest management in Ethiopia: Practices and experiences. Addis Ababa.

Woldemariam, T. and Senbeta, F. 2008. Sustainable management and promotion of forest coffee in Bale, Ethiopia. Bale Eco-Region Sustainable Management program, SOS Sahel/FARM-Africa, 24.

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.

Zegeye, H., Teketay, D. and Kelbessa, E. 2011. Diversity and regeneration status of woody species in Tara Gedam and Abebaye forests, northwestern Ethiopia. *Journal of Forestry Research*, **22 (3)**:315-328.

7. APPENDIX

Appendix 1: Questionery survey formats

1. Household Information

1.1. Name:______________________________

1.2. Code for household:____________________

1.3. Sex (Male/female):______________________

1.4. Age (years):______

1.5. How long the farm is under coffee (years):_________

1.6. Marital status (Single/ Married/ Widowed):_________

1.7. Family size _________________

1.8. Educational status of the household head: 1)Illiterate 2) Read and Write 3) Grade 1-4 4)5-8 5) 9-10 6) >10

1.9. Wealth Categories: Poor_____ Medium___________ Rich_______

1.10. Total landholding size ________________ha

2. Information on household annual income

2.1. What are the major household livelihoods?(e.g. Agriculture, forest related, Off-farm, remittance etc.)

2.2. What are major sources of cash that contribute to household income based on 2.1 above? rank first, second and third Agriculture (Crop,Livestock,Coffee,Chat,Honey)

First	Second	Third

2.3. What is your estimated average annual income of last year and this year ?

2.3.1. What are the annual quantities and values of crops that your household has harvested in year? Total cultivated landholding size _______ in hectare.

Crop Production	Area (ha)	Production (quintal/ha)	Sold	Consumption	Price per Unit	Total income
Maize						
Sorghum						
Teff						
Barley						
Other						

2.3.2. What is the number of animals that you had sold or slaughtered last year and this year?

Livestock	Number	Sold	Consumption	Price/animal	Total income
Cattle					
Sheep/goat					
Hen					
Other					

Product of livestock used

Product/Service	Production	Unit	Sold	(Own use or gifts given)	Price/unit	Total income
Milk						
Butter						
Cheese						
Eggs						
Other						

2.3.3 Income gain from forest products

Activities	Productivity	Sale	Consumption	Price/unit	Total income
Coffee					
Honey					
Timber					
Off farm					
Remittance					
Other specify					

3. Forest products obtained from coffee agroforestry and natural forest for household use. For coffee agroforestry, land holding size________________ hectare.

No.	Forest product categories	NF	Purpose of use (Market / consumption)	CAF	Purpose of use (Market /consumption)	Income
	NTFP					
1	Honey(modern)					
2	Honey(local)					
3	cardamom					
4	Timiz					
5	Gesho					
6	Lianas					
7	Medicinal plants					
8	Fruits/seeds					
9	Construction					
10	charcoal					
11	fuel wood					
12	Coffee					
13	Forest coffee					

4. How do you see the forest products you collect from the forest at different times?

No.	Forest product (Lower, Medium, Higher)	Natural Forest		Coffee Agroforestry	
		At present (after 5 Yrs)	Before 5 Yrs	At present (after 5 Yrs)	Before 5 Yrs
	Timber				
	NTFP				
1	Honey (modern)				
2	Honey (Local)				
3	Cardamom				
4	Timiz				
5	Gesho				
6	Lianas				
7	Medicinal plants				
8	Fruits/seeds				
9	Construction				
10	Charcoal				
11	Fuel wood				
12	Coffee				
13	Forest coffee				

5. How do you describe the status of existing Coffee forestry and natural forest with previous times?

Indicators (Decreasing, Increasing, no change)	Current status Main Reason
Forest area	
Species composition	
Different products types	

6. How do you rate coffee agroforestry and natural forest use?

Access use	Natural forest	Coffee agroforestry
Timber (Restricted/common)		
NTFP (Restricted/ common)		
Ownership feeling (private/ common)		
Household benefits (low/ high)		

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

8. Important woody Species in the area top ten.

No.	Species Name	Uses of the species
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

8.1 How do you prefer these woody species a cross coffee agroforestry and natural forest.

No.	Species Name	Natural forest(Decreasing, Increasing, No change, Lost)	Coffee Agroforestry (Decreasing, Increasing, No change, Lost)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Appendix 2: Botanical name of woody species in natural forest

Botanical Name	Vernacular name (Afan Oromo)	Family	Growth Habita
Allophylus abyssinicus (Hochst.) Radlkofer	Se'o	Sapindaceae	Tree
Apodytes dimidiata E.Mey.ex Am.	Wandabiyoo	Icacinaceae	Tree
Bersama abyssinica Fresen.	Lolchiisaa	Melianthaceae	Shrub
Brucea antidysenterica J.F. Mill.	Qomonyoo	Simaroubiaceae	Shrub
Byttneria catalpitiolata Jacq.	Haleele	Sterculiaceae	Tree
Calpurnia aurea (Ait.) Benth	Ceekaa	Fabaceae	Shrub
Celtis africana Burm.f.	Qahee	Ulmaceae	Tree
*Clausena anisat*a (Wild.) Hook. F.ex. Benth	Ulumaaye	Rutaceae	Shrub
Clerodendrun myricoides (Hochst.) Vatke	Marasissaa	Lamiaceae	Lianas
Combretum paniculatum A.Rich.	Baggee	Menispermaceae	Lianas
Cordia africana Lam.	Waddeessa	Boraginaceae	Tree
Croton macrostachyus Del.	Bakanisa	Euphorbiaceae	Tree
Diospyros abyssinica (Hiern.) F.White	Lookoo	Ebenaceae	Tree
Dracaena afromontana Mildbr.	Emoo	Dracaenaceae	Shrub
Ehretia cymosa Thonn.	Ulaagaa	Boraginaceae	Shrub
Ekebergia capensis Sparm.	Somboo	Meliaceae	Tree
Entada abyssinica Steud. ex A. Rich.	Hambaltaa	Fabaceae	Tree
Erythrina brucei Schweinf	Waleensuu	Fabaceae	Tree
Euclea racemosa	Mi'eessaa	Ebenaceae	Shrub
Fagaropsis angolensis (Engl.) Dale	Siglu	Rutaceae	Tree
Ficus sycomorus L	Harbuu	Moraceae	Tree
Ficus thonningii Blume	Dembii	Moraceae	Tree
Flacourtia indica (Brm.f.) Merr	Akuukkuu	Flacourtiaceae	Shrub
Galineria saxifraga (Hochst.) Bridson	Simararuu	Rubiaceae	Shrub
Hippocratea africana (Willd) Loes	Xiyoo	Celasteraceae	Lianas
Hippocratea pallens Planchon ex Oliver	Dikiicha	Celasteraceae	Lianas
Ipomoea marmomrata Britten & Rendle	Omboroke	convolvulaceae	Shrub
Jasminum abyssinicum Hochst. ex DC.	Hidda Ichilibe	Oleaceae	Lianas
Landolphia buchananni (Hall.f.) Stapf	Yebo	Apocynaceae	Lianas
Maesa lanceolata Forssk.	Abbayyii	Myrsinaceae	Shrub
Maytenus arbutifolia (A.Rich.) Wilczek	Kombolcha	Celasteraceae	Shrub
Millettia ferruginea (Hochst.) Bak	Askira	Fabaceae	Tree
Olea capensis L.	Gajjaa	Oleaceae	Tree
Olea europaea	Ejersa	Oleaceae	Tree
Olea welwitschii (Knobl.)Gilg. & Schellenb	Baya	Oleaceae	Tree
Paullinia pinnata L.	Hidda gagura	Sapindaceae	Lianas
Phoenix reclinata Jacq.	Meexii	Arecaceae	Tree

Phytolacca dodecandra L.Herit.	Handoodee	Phytolaccaceae	Lianas
Piper capense L.F.	Tunjo	Piperaceae	Lianas
Pittosporum viridiflorum Sims	Soole	Pittosporaceae	Tree
Podocarpus falcatus (Thunb.) C.N.Page	Birbiirsa	Podocarpaceae	Tree
Polyscias fulva (Hiern) Harms	Kariyo	Araliaceae	Tree
Pouteria adolfi-friederici (Eng.) Baehni	Qararoo	Sapotaceae	Tree
Premna schimperi Engl.	Qorasuma	Lamiaceae	Shrub
Prunus africana (Hook.f) Kalkm	Omoo	Rosaceae	Tree
Rhamnus prinoides L.Herit.	Geeshoo	Rhamnaceae	Shrub
Rytigynia neglecta (Hiern) Robyns	Mixoo	Rubiaceae	Shrub
Sapium ellipticum (Krauss) Pax	Bosoqqaa	Euphorbiaceae	Tree
Schefflera abyssinica (Hochst.ex.A.Ric) Harms.	Boto	Araliaceae	Tree
Syzygium guineense (Wild.) DC.	Baddeessaa	Myrtaceae	Tree
Teclea nobilis Del.	Hadheessa	Rutaceae	Shrub
Tiliacora troupinii Cufod.	Liqixii	Menispermaceae	Lianas
Urera hypselodendron (A.Rich.) Wedd.	Laanqisaa	Urticaceae	Lianas
Vernonia amygdalina Del.	Eebichaa	Asteraceae	Shrub
Vernonia auriculifera Hiern.	Reejjii	Asteraceae	Shrub

Appendix 3: Botanical name of woody species in coffee agroforests

Botanical Name	**Vernacular name (Afan Oromo)**	**Family**	**Growth Habitat**
Acacia abyssinica Hochst ex Benth.	Laaftoo	Fabaceae	Tree
Albizia gummifera (J.F.Gumel.) C.A.Sm	Hambabbeessa	Fabaceae	Tree
Allophylus abyssinicus (Hochst.) Radlkofer	Se'o	Sapindaceae	Tree
Bersama abyssinica Fresen.	Lolchiisaa	Melianthaceae	Shrub
*Clausena anisat*a (Wild.) Hook. F.ex. Benth	Ulumaaye	Rutaceae	Shrub
Clematis longicauda steud.ex A.Rich	Hidda nama gubbu	Ranunculaceae	Lianas
Clerodendrun myricoides (Hochst.) Vatke	Marasissaa	Lamiaceae	Lianas
Coffea arabica.L	Bunnaa	Rubiaceae	Shrub
Cordia africana Lam.	Waddeessa	Boraginaceae	Tree
Croton macrostachyus Del.	Bakanisa	Euphorbiaceae	Tree
Diospyros abyssinica (Hiern.) F.White	Lookoo	Ebenaceae	Tree
Dombeya torrida (J.F.Gumel.) P.Bamps	Daannisa	Sterculiaceae	Shrub\Tree
Ehretia cymosa Thonn.	Ulaagaa	Boraginaceae	Shrub
Ekebergia capensis Sparm.	Somboo	Meliaceae	Tree
Fagaropsis angolensis (Engl.) Dale	Siglu	Rutaceae	Tree
Ficus sycomorus L	Harbuu	Moraceae	Tree
Ficus vasta Forssk.	Qilxuu	Moraceae	Tree
Gouania longispicata Engl.	Homochiisa	Rhamnaceae	Lianas
Lepidotrichilia volkensii (Gurke) Leroy	Gursadi	Meliaceae	Tree
Millettia ferruginea (Hochst.) Bak	Askira	Fabaceae	Tree
Mimusops kummel	Eshee	Sapotaceae	Tree
Olea capensis L.	Gajjaa	Oleaceae	Tree
Persea americana Mill	Avocado	Lauraceae	Tree
Phoenix reclinata Jacq.	Meexii	Arecaceae	Tree
Polyscias fulva (Hiern) Harms	Kariyo	Araliaceae	Tree
Prunus africana (Hook.f) Kalkm	Omoo	Rosaceae	Tree
Rhamnus prinoides L.Herit.	Geeshoo	Rhamnaceae	Shrub
Sapium ellipticum (Krauss) Pax	Bosoqqaa	Euphorbiaceae	Tree
Sesbania sesban L. Merr	Sesbania	Fabaceae	Shrub
Stereospermum kunthianum Cham.	Dhama'ee	Bignoniaceae	Tree
Syzygium guineense (Wild.) DC.	Baddeessaa	Myrtaceae	Tree
Vernonia amygdalina Del.	Eebichaa	Asteraceae	Shrub
Vernonia auriculifera Hiern.	Reejjii	Asteraceae	Shrub

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

Natural Forest		Coffee agroforests	
Families Names	No. Species %	Families Names	No. Species %
Fabaceae	7.3	Fabaceae	12.1
Oleaceae	7.3	Rutaceae	6.1
Celasteraceae	5.5	Asteraceae	6.1
Rutaceae	5.5	Boraginaceae	6.1
Araliaceae	3.6	Euphorbiaceae	6.1
Asteraceae	3.6	Moraceae	6.1
Boraginaceae	3.6	Meliaceae	6.1
Ebenaceae	3.6	Rhamnaceae	6.1
Euphorbiaceae	3.6	Oleaceae	3
Lamiaceae	3.6	Araliaceae	3
Moraceae	3.6	Ebenaceae	3
Menispermaceae	3.6	Lamiaceae	3
Rubiaceae	3.6	Rubiaceae	3
Sapindaceae	3.6	Sapindaceae	3
Apocynaceae	1.8	Arecaceae	3
Arecaceae	1.8	Melianthaceae	3
convolvulaceae	1.8	Myrtaceae	3
Dracaenaceae	1.8	Rosaceae	3
Flacourtiaceae	1.8	Sapotaceae	3
Icacinaceae	1.8	Sterculiaceae	3
Meliaceae	1.8	Bignoniaceae	3
Melianthaceae	1.8	Lauraceae	3
Myrtaceae	1.8	Ranunculaceae	3
Myrsinaceae	1.8		
Phytolaccaceae	1.8		
Piperaceae	1.8		
Pittosporaceae	1.8		
Podocarpaceae	1.8		
Rhamnaceae	1.8		
Rosaceae	1.8		
Sapotaceae	1.8		
Simaroubiaceae	1.8		
Sterculiaceae	1.8		
Ulmaceae	1.8		
Urticaceae	1.8		

Appendix 5: Relative frequency, Relative abundance, Relative dominance and IVI of woody species in natural forest

Botanical Name	Rel. Frequency	Rel. Abundance	Rel. Dominance	IVI
Syzygium guineense	3.14	2.58	14.31	20.03
Croton macrostachyus	3.14	3.04	7.41	13.59
Maytenus arbutiolia	4.72	4.45	4.26	13.42
Olea capensis	3.46	5.15	4.58	13.19
Celtis africana	3.77	3.04	6.04	12.86
Pittosporum viridiflorum	3.77	3.28	5.24	12.29
Teclea nobilis	3.77	3.75	3.82	11.34
Pouteria adolfi-friederici	0.94	0.70	8.40	10.05
Flacourtia indica	2.83	2.81	3.87	9.51
Ehretia cymosa	2.83	3.75	2.90	9.47
Diosporyus abysssinica	2.52	3.28	3.27	9.07
Rytigynia neglecta	3.46	3.51	2.02	9.00
Apodytes dimidiata	1.89	2.34	4.20	8.43
Polyscias fulva	2.52	2.81	2.84	8.17
Dracaena afromontana	3.14	2.81	2.03	7.99
Calpurina aurea	3.46	3.28	1.12	7.86
Ekebegia capensis	2.20	1.64	3.85	7.69
Byttneria catalpitiolata	2.83	3.04	1.71	7.58
Galineria saxifraga	2.83	2.58	2.16	7.56
Allophylus abyssinicus	2.83	2.58	1.79	7.20
Ficus sycomorus	2.52	2.11	2.46	7.08
Euclea racemosa	2.20	2.34	1.88	6.43
Bersema abyssinica	1.89	2.34	0.96	5.19
Combretum paniculatum	2.20	2.34	0.15	4.70
Fagaropsis angolensis	1.89	1.64	1.07	4.60
Jasminum abyssinicum	2.20	2.34	0.04	4.58
Tiliacora troupinii	2.52	1.87	0.14	4.53
Landolphia buchananni	1.57	2.34	0.29	4.21
Olea europaea	1.57	1.41	0.76	3.73
Ficus thoningi	1.26	0.94	1.39	3.58
Hippocrata africana	0.94	1.87	0.05	2.87
Clausenia anisata	1.26	1.17	0.44	2.87
Cordia africana	0.94	0.94	0.98	2.86
Olea welwitschii	0.94	0.94	0.80	2.68
Clerodendron myricoides	1.26	1.17	0.03	2.46
Paullinia pinnate	1.26	1.17	0.02	2.45

Sapium ellipticum	0.94	0.70	0.69	2.33
Rhamnus prinoides	1.26	0.94	0.13	2.32
Vernonia amygdalina	0.94	1.17	0.20	2.32
Erythrina brucei	0.94	0.94	0.35	2.23
Piper capense	1.26	0.94	0.02	2.21
Maesa lanceolata	0.94	0.94	0.12	2.00
Premna schimperi	0.63	1.17	0.10	1.90
Hippocratea pallens	0.94	0.94	0.01	1.89
Brucea antidysenterica	0.94	0.70	0.18	1.83
Prunus africana	0.63	0.47	0.15	1.25
Phoenix reclinata	0.63	0.47	0.09	1.19
Millettia ferruginea	0.63	0.47	0.08	1.18
Vernonia auriculifera	0.63	0.47	0.03	1.13
Ipomoea marmomrata	0.63	0.47	0.02	1.11
Podocarpus falcatus	0.31	0.47	0.28	1.07
Entada abyssinica	0.31	0.47	0.04	0.82
Urera hypselodendron	0.31	0.47	0.00	0.79
Schefflera abyssinica	0.31	0.23	0.22	0.76
Phytolacca dodecandra	0.31	0.23	0.00	0.55

Appendix 6: Relative frequency, Relative abundance, Relative dominance and IVI of woody species in coffee agroforests

Botanical Name	Rel. Frequency	Rel. Abundance	Rel. Dominance	IVI
Coffea arabica	14.78	15.86	0.27	30.90
Millettia ferruginea	12.32	15.21	2.07	29.60
Albizia gummifera	6.90	11.00	3.17	21.07
Ficus sycomorus	6.40	4.21	8.10	18.71
Ficus vasta	0.99	0.65	17.06	18.69
Cordia africana	6.40	6.80	5.30	18.50
Bersema abyssinica	6.90	7.44	1.72	16.06
Ehretia cymosa	6.90	6.47	1.70	15.07
Sapim ellipticum	2.46	1.62	9.78	13.86
Syzygium guineense	4.93	4.85	2.57	12.36
Prunus africana	0.99	0.97	9.17	11.13
Vernonia amygdalina	5.42	4.21	0.56	10.18
Allophylus abyssinicus	0.99	1.29	7.24	9.52
Croton macrostachyus	1.48	0.97	6.87	9.31
Diosporyus abysssinica	2.46	2.59	3.22	8.27
Sesbania sesban	1.97	1.29	4.99	8.25
Persea Americana	2.96	3.56	1.34	7.86
Olea capensis	2.46	1.94	1.54	5.95
Ekebegia capensis	1.48	1.29	2.36	5.13
Polyscias fulva	1.97	1.29	0.72	3.99
Phoenix reclinata	0.49	0.32	2.57	3.39
Mimusops kummel	0.99	0.65	0.97	2.60
Gouania longispicta	1.48	0.97	0.11	2.56
Lepidotrichilia volkensis	0.49	0.65	1.29	2.43
Stereospermum kunthianum	0.49	0.65	0.97	2.11
Acacia abyssinica	0.49	0.32	1.29	2.10
Rhamnus prinoides	0.99	0.65	0.32	1.95
Clausenia anisata	0.99	0.65	0.16	1.79
Fagaropsis angolensis	0.49	0.32	0.97	1.78
Domboya torrida	0.49	0.32	0.64	1.46
Clemattis longicauda	0.49	0.32	0.32	1.14
Clerodendron myricoides	0.49	0.32	0.32	1.14
Vernonia auriculifera	0.49	0.32	0.32	1.14

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

Natural Forest		Coffee Agroforests	
Botanical Name	**Regeneration Status**	**Botanical Name**	**Regeneration Status**
Albizia gummifera	Fair	*Acacia abyssinica*	No Regeneration
Allophylus abyssinicus	Fair	*Albizia gummifera*	Fair
Apodytes dimidiata	Poor	*Allophylus abyssinicus*	Fair
Bersama abyssinica	Good	*Bersama abyssinica*	Fair
Brucea antidysenterica	Fair	*Clausena anisata*	No Regeneration
Byttneria catalpitiolata	Good	*Coffea arabica*	Good
Calpurnia aurea	Good	*Cordia africana*	Fair
Celtis africana	Good	*Croton macrostachyus*	Poor
Clausena anisata	Good	*Diospyros abyssinica*	Good
Cordia africana	Poor	*Dombeya torrida*	Poor
Croton macrostachyus	Fair	*Dracaena afromontana*	Poor
Diospyros abyssinica	Good	*Ehretia cymosa*	Good
Dracaena afromontana	Good	*Ekebergia capensis*	No Regeneration
Ehretia cymosa	Good	*Fagaropsis angolensis*	No Regeneration
Ekebergia capensis	Poor	*Ficus sycomorus*	No Regeneration
Entada abyssinica	Poor	*Ficus vasta*	No Regeneration
Erythrina brucei	Poor	*Lepidotrichilia volkensii*	Poor
Euclea racemosa	Good	*Maytenus arbutifolia*	Poor
Fagaropsis angolensis	Fair	*Millettia ferruginea*	Fair
Ficus sycomorus	Poor	*Mimusops kummel*	No Regeneration
Ficus thonningii	No Regeneration	*Olea capensis*	Good
Flacourtia indica	Good	*Persea americana*	Fair
Galineria saxifraga	Good	*Phoenix reclinata*	No Regeneration
Ipomoea marmomrata	Fair	*Polyscias fulva*	Fair
Lepidotrichilia volkensii	Fair	*Prunus africana*	No Regeneration
Maesa lanceolata	Poor	*Rhamnus prinoides*	No Regeneration
Maytenus arbutifolia	Good	*Sapium ellipticum*	No Regeneration
Millettia ferruginea	Good	*Sesbania sesban*	Good
Olea capensis	Good	*Stereospermum kunthianum*	No Regeneration
Olea europaea	Fair	*Syzygium guineense*	Poor
Olea welwitschii	No Regeneration	*Vernonia amygdalina*	Fair
Phoenix reclinata	No Regeneration	*Vernonia auriculifera*	No Regeneration
Pittosporum viridiflorum	Fair		
Podocarpus falcatus	No Regeneration		
Polyscias fulva	Good		
Pouteria adolfi-friederici	No Regeneration		
Premna schimperi	Good		
Prunus africana	No Regeneration		
Rhamnus prinoides	Good		
Rytigynia neglecta	Good		
Sapium ellipticum	Poor		
Schefflera abyssinica	No Regeneration		

Syzygium guineense	Fair
Teclea nobilis	Good
Vernonia amygdalina	Good
Vernonia auriculifera	Fair