Jimma University

College of Natural Sciences

School of Graduate Study

Department of Biology

Botanical Science Stream

Woody species diversity and aboveground live carbon storage in different land use type of Shabe Sombo District, Jimma Zone, Southwest Ethiopia

By: Megersa Deresa

Advisor: Dereje Denu (PhD)

Co-Advisor: Tamene Belude (M.Sc.)

A Thesis Submitted to the Department of Biology, College of Natural Sciences, School of Graduate Studies, Jimma University, in Partial Fulfillment for the Requirement of the Degree of Master of Science in Biology (Botanical Science).

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Approved by:

Name	Signature	Date
Dr. Dereje Denu (Advisor)	________	____________
Mr. Tamene Belude (Co-Advisor)	________	___________
____________________(External Examiner)	________	___________
_____________________(Internal Examiner)	________	___________
_____________________ (Chairman)	________	___________

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Abbreviations/Acronyms

AGB	Aboveground Biomass
AGC	Aboveground Carbon
BA	Basal Area
BNFPA	Belete National Forest Priority Area
DBH	Diameter at Breast Height
GHG	Green House Gas
GPS	Geographical Positioning System
IPCC	Intergovernmental Panel on Climate Change
IVI	Important Value Index
JU	Jimma University
NGO	Non-Governmental Organization
RA	Relative Abundance
RD	Relative Dominance
RF	Relative Frequency
SFC	Semi-Forest Coffee
SPM	Summary for Policy Maker
TROF	Tree Resources Outside of Forest
UNFCCC	United Nation Framework Convention on Climate Change

Abstract

This study was conducted on woody species diversity and aboveground live carbon storage under different land use types of Shabe Sombo District, Jimma Zone, Southwest Ethiopia, in 2017. The objectives of this study were, (1) to determine the diversity and richness of woody species, (2) to determine aboveground live carbon storage and sequestration in woody species biomass, (3) to compare woody species in semi-forest coffee land and other agricultural fields in terms of diversity as well as amount of carbon storage. Four transects in which different land use types of stratified were established at 1 km distance from each other across land use gradients. Forty two plots, each with one hectare, were laid in all land use types. Data on woody species and aboveground live carbon storage were collated from each plot. A total of 58 woody species belongs to 33 families and 43 genera were collected and documented. The sample specimens were identified using botanical keys of the published volumes of Flora of Ethiopia and Eritrea. Species diversity was determined by using Shannon diversity index. The aboveground live biomass for woody species with DBH ≥ 10 cm was calculated by using $AGB = 0.0673 \times (\rho D^2 H)^{0.976}$ *and AGC was estimated at 50% of AGB. In this study, 20.79 t AGC/ha was determined from the semi-forest coffee system, 6.73 t AGC/ha from pasture land and 4.28 t AGC/ha from crop land. The variation in carbon storage among different land use types was statistically significant (F = 34.21, P = 0).*

Key Words/phrases

Woody species diversity, aboveground live biomass, Carbon storage

CHAPTER ONE

1. Introduction

Ethiopia is an important regional center for biological diversity due to its wide ranges of altitude and its great geographical diversity (Ensermu Kelbessa *et al*., 1992). Biological diversity in its broadest sense includes all biotic variation from the level of genes to ecosystems (Purvis and Hector, 2000). Plant biodiversity is one of the major groups of biological diversity that encompasses all plant species in all places such as forests and agricultural landscapes. Forests are composed of high percentage of plant diversity and are considered as the lung of the planet due to their ability to sequester and store carbon in their biomass and reduce the amount of carbon dioxide in the atmosphere. Human activities like deforestation, overharvesting and permanent conversion to other forms of land use were leading to the decline of forest resources in Ethiopia (Adugna Feyissa, 2013).

The removal of plant species from natural habitat was the principal cause for increasing level of CO_2 accumulation in the atmosphere. The increment of carbon dioxide in the atmosphere is today's major global problem, because it is the most important cause for global warming (Lal *et al*., 2001). Many researchers, governmental and non-governmental organizations gave attention to forest section as one of the options to reduce greenhouse gas emissions. In addition to forests, plant species in different land use types could be taken as a good reservoir of carbon dioxide and hence help the global effort to mitigate climate change.

Therefore, studying the diversity of woody species, estimating and documenting the amount of carbon stored in different land use types is important in climate change mitigation. Agricultural landscapes host high number of woody species (Etefa Guyassa and Rej, 2013). This shows that, woody species (tree and shrubs) are the most important groups of plant species in different land use types. They have great ecological importance in agricultural landscapes. The presence of woody species serves as a nesting, roosting and feeding site for a variety of birds and it also enriches faunal biodiversity (Harvey and Haber, 1999). Woody species have a great biomass that store excessive carbon in such a way that they reduce greenhouse gas (GHG) accumulation in the atmosphere. When these plants removed by human activity, the carbon stored in their biomass is released back into the atmosphere (Vashum and Jayakumar, 2012). This means that trees store the sequestered carbon in their woody biomass. Most of the carbon in woody species is accumulated in aboveground live biomass. Aboveground carbon storage is the amount of carbon that is assumed to be 50% of the total tree biomass made up by carbon (Kumar and Nair, 2011).

In many studies, estimation of woody species biomass had been done by whole tree method. The biomass of a tree species is typically estimated by extracting several individuals in a sampling plot to determine the actual mass of that species; subsequently relating this mass to bio- metric variables through an allometric model (Whittaker and Woodwell, 1968). Even though this method is more accurate in the determination of the aboveground biomass (AGB) for a specific tree species at a given site, it is not applicable at the regional scale due to its destructive nature (Ali et al., 2015). Since this approach includes the cutting of tree for fresh mass measurement; it is not suitable for threatened species. However, it was an old approach, destructive and at the same time, was expensive. Therefore, woody species biomass was determined using allometric equations with different measured variables such as DBH, height and specific woody gravity (Kumar and Nair, 2011).

1.1. Statement of problem

Many studies have been conducted on forest ecosystems to know and document plant species richness, abundance, diversity, carbon storage and cause and effect of deforestation in Ethiopia. Attention has not been given to plant species in semi-forest coffee, pasture land and crop lands. Sometimes they were taken as extra plants which have no value except narrowing space for other activities. Conversely, plant species on different land uses are very important in storing carbon and mitigating climate change impacts, providing shade for other plant species like coffee, as forage for feeding livestock, producing edible fruits, for recreational and spiritual values, as habitat for other organisms and provide food and fuel. In short in different land use types, plants with different species serve diverse socio-economic, socio-cultural and ecological functions.

Due to absence of sufficient studies, there was no enough information on plant species richness, diversity and carbon storage in different land use types of the study area. Therefore, this study was conducted to assess and document the diversity of woody species and carbon storage in different land use types of Shabe Sombo district. The study was designed to address the following research questions.

1. What is the woody species composition in different land use types of the study area?
2. Is there any difference in woody species richness and diversity between semi- forest coffee land and other agricultural fields?
3. How much carbon is stored in living aboveground biomass of woody species in different land use types?

1.2. Objectives of the study

1.2.1. General objective

The overall objective of this study was to investigate woody species diversity and to estimate aboveground live carbon storage in different land use types of Shabe Sombo District, Southwest Ethiopia.

1.2.2. Specific objectives

1. To determine woody species composition in different land use types of the study area.

2. To compare woody species diversity in semi-forest coffee land with other agricultural fields.

3. To estimate carbon stored in living aboveground biomass of woody species in different land use types.

1.3. Significance of the study

The findings of this study provide basic information on woody species diversity and carbon storage in different land use types of Shabe Sombo District. It may be used as a baseline information that would help the future management and conservation of plants in different land use types. It also provides organized document for researchers, government and non-governmental organizations (NGO) for further studies.

CHAPTER TWO

2. Related literature review

2.1. Woody species diversity and their role in conservation of biodiversity on agricultural landscapes.

Species diversity has been identified as one of the key indices in sustainable land use practices and resource management (Schackelton, 2000). Plant species diversity has often been noted for prioritizing conservation activities since they reflect the underlying ecological processes that are important for management (Lovett *et al.*, 2000). Conservation of woody species at the levels of ecosystems, landscapes, community, populations, individuals and genes, is essential to sustain the health and vitality of ecosystems (Wondie Mebrat and Temesgen Gashaw, 2013).

More than half of the Earth's terrestrial surface is molded by agriculture. The contribution of agricultural landscape to biodiversity is critical for successful long-term conservation activities (Tallis *et al*., 2009). Agricultural landscape plays a key role in the conservation of native woody species diversity. The presence of woody species in these land use type may help for the existence of other living organisms and therefore, provides to a wider conservation of biological diversity. Trees and shrubs in crop and pasturelands have huge ecological importance. They act as windbreaks, protecting crops from wind damage; help in soil and water conservation and provide other ecosystem services. Their shade helps to reduce the temperature of the soil. Remnant woody species in crop fields may play an important role in conserving biodiversity within agricultural systems, because, they provide habitats and resources that are otherwise absent from agricultural landscapes (Harvey and Haber, 1999). In order to support the conservation of useful woody species, it is necessary to explain the importance of woody species for the local people. The major uses of woody plants include fencing and fuel wood (Belay Tefera *et al.*, 2014).

In other ways, the decline of woody species diversity in agricultural lands enhances nutrient loss which could affect the survival of biological diversity in farm lands. Thus, nutrients are lost in the burning process by two pathways: loss by removal of plant material from the field and loss into the atmosphere during burning (Nguyen *et al*., 2008). Woody species diversity and density declined with increasing age of the crop fields and this relates to the change in distance between crop fields and natural forest over time (Tolera Motuma *et al.,* 2008). This shows that degradation of forest also causes the loss of plants in agricultural lands. The continuous reduction in woody species on crop fields may not only create shortages of forest products in the long run but also deterioration of biodiversity and reduction of other ecological services in the farming system (Tolera Motuma *et al.,* 2008). The reduction of woody species diversities in agricultural lands could also be caused by increasing monoculture plantation. The representation of many species with only few individuals in the farming systems shows their low density and isolation, as well as the risks of reduced gene flow and reduced ability for long term survival (Boshier, 2004).

2.2. Concept of agroforestry

Agroforestry is a farming system that integrates crops and/or livestock with trees and shrubs. These have great potential for reducing deforestation and forest degradation, providing habitat for other organism and to conserve woody species within farm lands. Agroforestry systems involve careful selection and management of trees and crops to optimize the production without compromising biodiversity (Parrotta and Trosper , 2012).Traditional agroforestry practices play a major role in the conservation of native woody species like *Syzygium guineense* and *Juniperus procera* in Ethiopia (Abiot Molla and Gonfa Kewessa, 2015). Traditional and recently modified agroforestry systems can offer advantages over conventional agricultural and forest production methods (Parrotta and Trosper, 2012). These have great potential for reducing deforestation and forest degradation, providing habitat for other organisms and to conserve woody species within farm lands of the farmers. The major benefits people obtain from on farm trees include fuel wood, soil fertility, construction, fodder, fencing, farm tools, shade, fruit, medicine and income from fruit and planted commercial trees (Etefa Guyassa and Raj, 2013). It is an ecological centered natural resources management method through integration of trees on farms of diverse agricultural landscapes and encourages production of economic and ecological benefits. Agroforestry systems can mitigate greenhouse gas (GHG) emissions, conserve biodiversity and generate income (Ha, 2012). This means, if agroforestry is carefully practiced in the country; they absorb carbon dioxide from the atmosphere and reduce the level of global warming. There is increasing evidence that as natural forest becomes degraded; farmers in many situations have historically taken up the planting and management of trees on their lands to provide the needed outputs (Arnold, 1990).

According to Ramachandran, *et al*. (2009) agroforestry systems that integrate tree production with crop and animal production systems are believed to have a higher potential to sequester carbon than pastures or field crops. This estimation is based on the idea that tree incorporation in croplands and pastures would result in greater net aboveground as well as belowground carbon sequestration. Therefore, agroforestry is essential in climate regulation through carbon sequestration and storage in their biomass; helps in biodiversity conservation and in solving the problem of food security.

2.3. Economical, ecological and sociocultural use of woody species in agricultural landscape

Woody plants serve a wide variety of economic, sociocultural, and ecological functions within different land use types. In addition to coffee shade and other non-timber products and services, people in southwest Ethiopia use agroforest trees for various wood products and fuel on a day-to-day basis (Getachew Tadesse *et al*., 2014). Woody plants are also used as fodder, construction materials, sources of income, traditional medicines, improving soil fertility, furniture, spiritual practices (Belay Tefera *et al*., 2014). In general, woody species are essential for soil nutrient conservation, carbon storage, erosion control, and regulation of environmental climate. The retention woody species in agricultural landscapes depends on local ecological knowledge regarding the use and conservation of species (Martin,1995; Neba, 2009).

Conservation of woody plant diversity within agricultural landscapes is therefore critical to farmers' livelihoods. Farmers protect plant and promote woody species within and around their home gardens, fields, and communal pasturelands to derive a range of benefits, including provisions of food, fodder, construction materials, farm equipment, fuel wood, and medicines (Belay Tefera *et al.*, 2013). In general, woody species are essential for regulating ecosystem services (provide food, oxygen, shelter, recreational and spiritual value, source of commercially trended products like timber, medicine, cloth), soil nutrient conservation, carbon storage, erosion control, shade and regulation of environmental climate.

2.4. Factors affecting woody species diversity in agricultural landscapes.

Considering the factors that govern woody species diversity existence in various part of the country is therefore of the highest importance, and necessary in developing woody species conservation strategies in agricultural lands. Human disturbance has been identified as one of the main drivers of woody species success in agricultural lands. The rapid population growth for example, leads to expansion of agricultural land, over grazing, increased exploitation of fuel wood and construction material (Dereje Denu, 2007). This suggests that, as the need of people increases, they put pressure on plant of agricultural land as well as whole plant diversity in forests.

Human activities, especially the burning of fossil fuels, have caused an increase in the concentration of carbon dioxide (CO_2) in the atmosphere, which is a large contributor to climate change (Free, 2010). This means, climate change is the result of human activity and is one of the highest elements that disturb environmental conditions. Therefore, human beings have direct impacts on agricultural woody species diversity through species removal and also alter the features of the ecosystem such as vegetation structure and soil properties. They cut woody plants for direct use without replacing which is an indication for unsustainable resource use. When deforestation occurs, trees can be replaced by non-tree vegetation such as grasses or crops. In this case, the new land use has consistently lower plant biomass and often soil carbon, particularly when converted into annual crops. The loss of natural vegetation due to human induced impacts is going on and yet not checked (Dereje Denu and Tamene Belude, 2012). If this remains unchecked for long, it is the great alarm for the coming generation to be affected by scarcity of ecosystem service.

In addition to deforestation, livestock-induced disturbances might be among the major factors limiting regeneration and removal of woody species. Disease and lack of technical knowledge in managing exotic woody species is also another aggravating problem affect woody species (Getahun Yakob *et al*., 2014*).* Environmental factors such as rainfall, altitude and soil properties, could also affect woody species diversity. For example, the inefficiency of carbon dioxide and water from the environment decreases the rate of photosynthesis by woody species and in turn this minimizes their diversities.

2.5. Climate change and its mitigation

2.5.1. Climate change

Climate change refers to a change in average weather conditions, or in the time variation of weather around longer-term average conditions. Global climate change leads to rising temperatures, sea-level rise, changing weather patterns, and more unpredictable weather events. Climatic change can impact environmental norms and human populations, causing serious negative impact to the global economy (Telemos Seta and Sebsebe Demissew, 2014).Climate change is directly put effect on population size of plant species in different land use types; including variety of forests, plants in agricultural landscapes and in the home gardens. Woody species are plants that govern climate change through carbon storage in their biomass. Ecological function of woody species (like balancing of atmospheric air) is understudied in our country with the exception of economical function (like lumber, charcoal, construction), that is the main cause of falling the number of woody species to enhance climate change in the country.

The cause of climate change could be either natural such as volcanic eruptions or human activities (Scholes *et al*., 2010). The rise of CO_2 concentration in the atmosphere is mainly attributed to human activities. The burning of fossil fuels caused an increase in the concentration of carbon dioxide (CO_2) in the atmosphere (a large contributor to climate change) (Free, 2010). Variation in the atmospheric concentration of some GHGs has important consequences for the warming effect (Denich and Puig, 2005).

Global warming refers to an increase of surface temperature, while climate change includes global warming and everything else that increasing greenhouse gas levels (Denton, 2014). Small changes in the global atmospheric temperature are expected to modify rainfall patterns, raise the sea level and increase the frequency of extreme weather events, with subsequent economic and social impacts (Denich and Puig, 2005). The rise in the carbon dioxide level in the atmosphere is mainly caused by anthropogenic activities. In the 19th century, with the advent of industrial revolution, humans have been burning a huge amount of fossil fuels, releasing the carbon stored in it back into the atmosphere as carbon dioxide (Vashum and Jayakumar, 2012). In general, both natural events and human activities are identified as main causes of climate change. It is increasingly recognized that agricultural and forest management strategies to deal with climate change should consider all relevant knowledge and historical experiences that have helped societies adapt to changing environmental conditions (Parrotta and Trosper, 2012).

2.5.2. Climate change mitigation

It consists of actions to limit the magnitude or rate of long term climate change (Fisher, 2007). Climate change mitigation generally involves reductions in anthropological emissions of greenhouse gases (GHGs). Mitigation may also be achieved by increasing the capacity of carbon sinks through reforestation (IPCC, 2007). It is an intervention to reduce the emissions sources or enhance the GHG sinks, whereas adaptation is the adjustment in natural or human systems in response to actual or expected climatic change or their effects, to reduce harm or exploit beneficial opportunities. Reducing human induced greenhouse gas emissions and adapting to the impacts of climate change are the two different ways to address climate change. Examples of mitigation include switching to low-carbon energy sources, such as renewable and carbon neutral energy sources and expanding forests and plant species on agricultural lands to remove carbon dioxide from the atmosphere. The ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to stabilize atmospheric concentrations of GHGs at a level that would prevent dangerous human interference of the climate system. In 2010, Parties to the UNFCCC agreed that future global warming should be limited to below 2.0 °C (3.6 °F) relative to the pre-industrial level (Keskitalo, 2011).

The mitigation policies might be able to limit global warming by 2100 to around 2°C or below, relative to pre-industrial levels (SPM, 2014). Without mitigation, increased energy demand and extensive use of fossil fuels might lead to global warming. Higher magnitudes of global warming would be more difficult to adapt to, and would increase the risk of negative impacts (Field, 2014). Climate change is the most freighted condition for survival of all living things on this planet unless it has been mitigated. Climate change mitigation could be enhanced through increasing carbon sequestration (reforestation and afforestation), encouraging plants that store more carbon (eg. woody species) and developing awareness for local peoples about the use of plants in climate change mitigation.

2.5.2.1. Carbon sequestration

Carbon dioxide is captured from the atmosphere by plants and converted into organic food through photosynthesis. Some of the synthesized food is used to build the tissue of the plants and are stored in the plant as biomass. Carbon sequestration is the process involved in carbon capture and the long-term storage of atmospheric carbon dioxide (CO_2) in the biomass of the plant (Sedjo and Sohngen, 2012). It has been proposed as a way to slow the atmospheric and marine accumulation of greenhouse gases which are released from burning of fossil fuels. The carbon sequestration is a process that help the achievement of carbon dioxide balance in the atmosphere and maintain the global carbon cycle which has been happening since billions of years ago (Vashum and Jaykumar, 2012).The natural storage of CO_2 by aboveground biomass (trees) is one of the effective techniques for mitigating the atmospheric CO_2 levels (Jina *et al*., 2009). So, the presence of permanent woody species (tree and shrub) system components enhances carbon storage basically in aboveground biomasses. Woody species can store excessive carbon in their biomass, after it has been captured in the form of CO_2 from atmosphere during photosynthesis.

2.6. Biomass and carbon storage

2.6.1. Biomass

In ecology, biomass refers to the mass of all living matter present in a given area, including all flora and fauna (Free, 2010). There are different carbon pools of terrestrial ecosystem involving biomass such as, aboveground biomass, and belowground biomass. The aboveground live biomass of a tree constitutes the major portion of these carbon pools (Vashum and Jayakumar, 2012). Aboveground biomass refers to the sum of the dry weight of stems, branches and leaves and the bark was not removed from stems or branches, and all branches were included in aboveground biomass (Chen, 2015). Most of the carbon in trees and shrubs is accumulated in aboveground biomass (AGB) and 50% of the total biomass is taken as carbon stock (Chave *et al*., 2014). Therefore, woody species (trees and shrubs) can accumulate large amount of carbon in their aboveground biomass.

2.6.2. Carbon storage

Carbon storage refers to the actual amount of carbon contained in plants, soils, oceans, and other non-atmospheric stores (Free, 2010). Unlike carbon sequestration, carbon storage does not refer to the process or rate of carbon uptake from the atmosphere. To convert biomass to carbon storage, the 50% of the woody species biomass was used (Baishya *et al*., 2009). The carbon content in the biomass is obtained by multiplying with 0.50 (Chave *et al*., 2014), while multiplication factor 3.67 needs to be used to estimate CO_2 equivalent from estimated carbon.

Carbon dioxide is one of the greenhouse gases that can be removed from the atmosphere by trees through photosynthesis. This process involves plant cells converting the carbon from carbon dioxide to a solid form in sugars (the carbohydrates glucose and starch) that can be stored in different parts of plans (in leaves, stems, trunks, branches and roots) and contribute to tree growth. The amount of carbon stored in trees depends on a number of factors including tree species type, growth conditions, age of the tree and tree density. These carbon stored in woody plant is released back to the atmosphere only when the wood product is burnt or decays or when people use woody plants for different purposes. TROFs (Tree Resources Outside Forests) may also undoubtedly and significantly contribute to the net CO_2 reduction in the atmosphere if promoted and help check global warming (Namayanga, 2002). This shows that woody or tree plants occupy outside of the forest in different parts of the landscapes such as grazing land, crop land and home gardens are obviously important to remove CO_2 from atmosphere in climate change mitigation. The carbon that stored in the biomass of woody species can be estimated by using standard formulas like allometric equation.

CHAPTER THREE

3. Materials and methods

3.1. Description of study area

3.1.1. Geographical location

This study was conducted in Shabe Sombo District, Jimma Zone, Oromia Regional State, southwest Ethiopia. Shabe Sombo is about 394km far from Addis Ababa and 48km from Jimma town. It is the home of Belete National Forest Priority area (BNFPA) and is found on the main road from Addis Ababa to Mizan Tepi. The district with the area of 76,558.391ha is located within geographical coordinates of 7^{o} 17'00'' to 7^{o}44'00''N Latitude and 36^{o}17'00' to 36^{o}52'00''E Longitude and the study area is situated between 1200m and 2440m a.s.l.

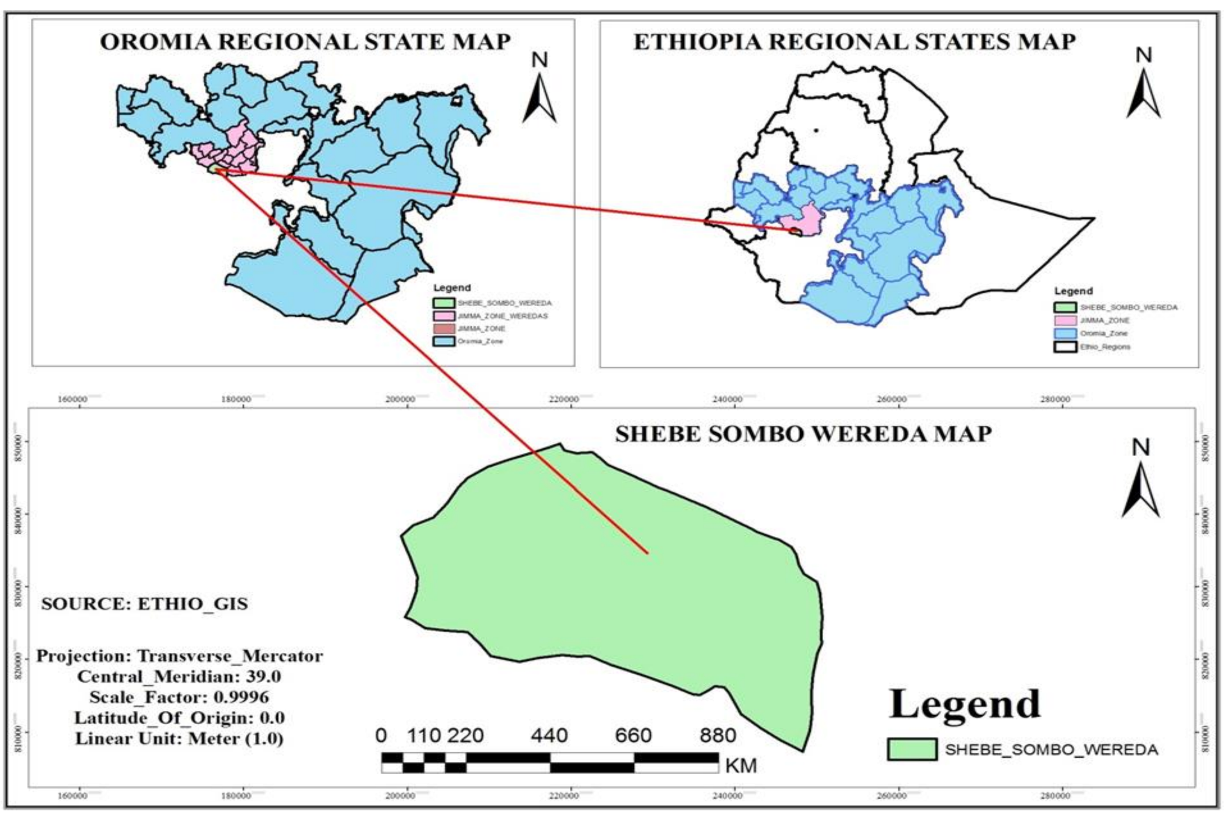

Figure 1: Map of the study area (Shabe Sombo District) in 2017.

3.1.2. Climate

Meteorological data obtained from National Meteorology Service Agency (Jimma Zone) indicates that, Shabe Sombo district receives its maximum rainfall during summer season (June-August). The average annual rainfall was about 1500mm to 1800mm and average temperature was 19C^o to 23C^o. Generally, rainfall exists from March throughout October and temperature becomes severe in the months of January, February and March. Cooler condition is experienced in summer season (June-August).

3.1.3. Vegetation

The vegetation of the study area was highly dominated by species such as *Ekebergia capensis, Diospyros abyssinica, Olea welwitschii, Prunus africana, Sapium ellipticum, Cordia africana*, *Millettia ferruginea*, *Croton macrostachyus* and *Acacia abyssinica*. Remnants of these species are found in semi-forest coffee, crop lands and pasture lands.

3.1.4. Economic Activity

The major economic activity of the study area was agriculture, particularly mixed farming (rearing of animals and crops). The most widely cultivated cash crop in the study area is coffee. The cereal crops include maize, teff, sorghum, millet and barley, pulse crops are also common (beans, peas) and soy bean. A commonly found domestic animal in the study area includes cattle, sheep, goats, horses, donkeys and poultry.

3.1.5. Human settlement and land use

The total population of Shabe Sombo is about 125,645. The majority of the population lives in the rural area and depends on agriculture. The major ethnic group is Oromo, major spoken language is Afan Oromo and the majority of the people are Muslims.

3.2. Methodology

3.2.1. Material

Geographical Positioning System (GPS), Clinometer, measuring tape, digital camera, specimen holder, Plant press, plastic bag, glove, plant cutter, marker, and hand calculator had been used.

3.2.3. Preliminary survey

A preliminary survey in the study area was conducted before actual data collection (in the 7th month of 2009 E.C.) .This is to obtain general information about the study area or nature of the site conditions, to select sampling site, to be familiar with the environment and for feasibility of study.

3.2.4. Data type

Both primary and secondary data were used in order to meet the objectives of this study. Primary data were obtained through field work and the secondary data (wood specific gravity for each tree species) was taken from global wood density data base, developed by Chave *et al*. (2009).

3.2.5. Sampling Design

Four transects were laid at a distance of 1km from each other. These transects were stratified into different land use types. Fourteen plots of size 100 m × 100 m (total = 42 plots) were randomly laid in each land use types (Semi-forest coffee, cropland, pastureland) along the study transects.

3.3. Data collection

The data collection was conducted throughout 8th months of 2009 E.C. All the woody species in the plots were collected and recorded. Data on tree DBH (at 1.3 m above the ground) and height >2m of those with DBH $\geq$ 10 cm were collected from 100m × 100m (1ha) plots. For the stem abnormalities, we followed Rainfor protocol (Phillips *et al*., 2009). All woody species with DBH

≥10cm were counted; their circumference and height were measured. Wood specific gravity for each tree species was taken from global wood density data base (Chave *et al*., 2009).

3.3.1. Woody species identification

To analyze the diversity of woody species and to estimate the aboveground live biomass and to calculate carbon storage in the study area, all woody species with DBH ≥10 cm were identified and recorded. The sample specimens were properly pressed and brought to Jimma University and the voucher specimens were deposited at JU Herbarium. The species were identified using botanical keys from the published volumes of Flora of Ethiopia and Eritrea.

3.4. Data analysis

All tree and shrub species recorded in all plots were used in the analysis of diversity and structure. Data was analyzed by using Microsoft excel spread sheet and descriptive statistical methods such as percentage and frequency distribution. Density, frequency and richness data obtained from semi-forest coffee was compared with other land use types. SPSS version 20 was used in the analysis.

3.4.1. Woody species diversity analysis

Shannon-Wiener (1949) diversity index was used to measure species diversity.

$$H' = -\sum p_i \ln p_i$$

H' = Shannon diversity index.

Pi = the proportion of individuals of the i^{th} species expressed as a proportion of the total cover;

ln = log base n (natural logarithm).

Shannon's Equitability (E), Evenness was calculated from the ratio of observed diversity to maximum diversity using the flowing equation

$E = H'/H'_{max}$, $H_{max} = \ln S$

Where, H` = Shannon-Diversity Index

S = total number of species in the sample

ln = natural logarithm

The value of evenness index falls between 0 and 1. The higher the value of evenness index, the more even the species is in their distribution within the given area.

3.4.2. Similarity Index (Ss)

Sorensen similarity index was used to compare woody species composition in semi-forest coffee with other land use types. The similarity index was calculated from the following formula:

$$Ss = \frac{2a}{(2a + b + c)}$$, where:

Ss = Sorensen similarity coefficient

a = number of species common to both sites

b = number of species unique to the first site

c = number of species unique to the second site

3.4.3. Woody species structural analysis

All woody species recorded in the study plots were used in the structural analysis. Diameter at breast height (DBH), frequency, height, importance value index (IVI), basal area of tree species was analyzed. DBH measurement was taken at about 1.3 m from the ground using a measuring tape.

Basal area

Basal area of all woody species with DBH $\geq$ 10 cm was calculated using the following formula.

$BA = \pi (DBH/2)^2$ Where: BA = Basal area, DBH = Diameter at breast heat, $\pi = 3.14$

DBH values were calculated from circumference measurements, $D = C/\pi$

Height

Height is a straight forward parameter used for direct measurement of carbon storage. Distance from the observer to the tree was measured. The angle between the observer and the tip of a tree was measured and recorded by Clinometer. The height of the tree was calculated from the distance and angle data using a trigonometric relation.

The trees in SFC of the study area were examined by grouping in to three main storey. Trees with > 2/3 height of the top height represents upper storey, trees with height between 1/3 and 2/3 of top height represents the middle storey and the lower storey is represented by trees with height < 1/3 of the top height.

Density

Density is defined as the number of individuals of a species within the plots (Kent and Coker, 1992). It is closely related to abundance but more useful in estimating the importance of a species. It is the number of stem count or total number of individual in the area. It was calculated by summing up all stems across all area and converting into hectare.

$$\text{Density} = \frac{\text{Total number of individuals}}{\text{Sampled area in hectare}}$$

$$\text{Relative density (RD)} = \frac{\text{Number of individuals of a species}}{\text{Total number of all individuals}} \times 100$$

Frequency

Frequency is the number of times a particular species is recorded in the sample area. The high frequency value of a given plant species in a community indicates that it is widely distributed in the area.

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of a woody species}}{\text{Frequency of all woody species}} \times 100$$

$$\text{Relative dominance (RDM)} = \frac{\text{Basal area of a species}}{\text{Total basal area of all species}} \times 100$$

Importance Value Index (IVI)

Importance Value Index combines data from three parameters (Relative frequency (RF), Relative density (RD) and relative dominance (RDO) (Kent and Coker, 1992). It was stated that species with the highest importance value index are the leading dominant of given vegetation (Simon Shibru and Girma Balcha, 2004). This index shows the significance of species in the system and calculated as follows:

$$\text{Importance value index (IVI)} = \text{Relative Density} + \text{Relative dominance} + \text{Relative frequency}$$

3.4.4. Aboveground biomass and carbon storage

3.4.4.1. Aboveground biomass

There are different equations that have been developed by many researchers to estimate the aboveground biomass. For this study, we used the revised non-destructive allometric equation developed by Chave *et al*. (2014) to calculate the aboveground live biomass (AGB) of each woody species, given as a function of DBH, height and wood specific gravity.

$\mathbf{AGB = 0.0673 \times (\rho D^2 H)^{0.976}}$ Where: ABG = Aboveground biomass, ρ = Wood specific gravity, D = Diameter at breast height, H = Height

3.4.4.2. Estimation of aboveground carbon storage

The aboveground live carbon (AGC) was estimated at 50% of the AGB for each woody species with DBH $\geq$ 10 cm (Chave *et al*., 2014).

AGC = 0.5×AGB Where: AGC = aboveground live Carbon, AGB = above ground biomass.

Aboveground live carbon storage was calculated for each land use type in the study area. The variation in AGC among different land use types of the study area was analyzed using one way ANOVA. The data were checked for normality before using ANOVA which is a parametric test.

CHAPTER FOUR

4. Result and Discussion

4.1. Results

4.1.1. Woody species composition

In the study area, a total of 58 woody species (47 Trees and 11 Shrubs), belonging to 33 families and 53 genera were recorded from three land use types (Semi-forest coffee, Pasture land and crop lands) (Appendix.1). Fabaceae was the most dominant family with seven species (12.07%) and seven genera (13.21%), followed by Euphorbiaceae and Moraceae each with five species (8.62%) and four genera (7.55%). Myrtaceae is composed of and four species (6.90%) and three genera (5.66%). Rubiaceae and Rutaceae are represented by three species (5.17%) and three genera (5.66%), Anacardiaceae by two species (3.448%) and two genera (3.77%), Boraginaceae by two species (3.448%) and two genera (3.77%) and Asteraceae by two species (3.448%) and one genus (1.88%).The remaining 24 families were represented by one species (1.72%) and one genus each (1.88%) (Appendix 2).

Table 1: Families with ≥2 species in the study area in 2017

Family	Number of species	Percentage (%)
Fabaceae	7	12.069
Euphorbiaceae	5	8.621
Moraceae	5	8.621
Myrtaceae	4	6.987
Rubiaceae	3	5.172
Rutaceae	3	5.172
Anacardiaceae	3	3.448
Asteraceae	2	3.448
Boraginaceae	2	3.448
Total	34	58.71

The woody species collected and recorded from the study area were distributed throughout three land use types (semi-forest coffee, Pasture land and crop lands). Out of 58 species in the study area, 45 species (77.59%) belong to semi-forest coffee, 40 species (68.97%) to pasture land and 29 species (50%) to crop land. Fourteen species (24.14%) were common for the three land use types, 27 species (46.55%) common to semi-forest coffee and pasture land, 25 species (43.10%) common to semi-forest coffee and crop lands, 19 species (32.76%) common to pasture and crop lands, eight species (13.79%) unique for semi-forest coffee, seven species (12.07%) are unique for pasture land and only one species (1.72%) is unique to crop land.

Table 2: Distribution of tree and shrubs species in three land use types

	Habit		
Land use type	Tree	Shrubs	Total
Semi-forest coffee	37	8	45
Pasture land	33	7	40
Crop land	24	5	29

4.1.2. Woody species diversity, richness and evenness

From the current study, the result attained demonstrated that, semi-forest coffee in the study area has the highest richness of the woody species compared to the remaining two land use types.

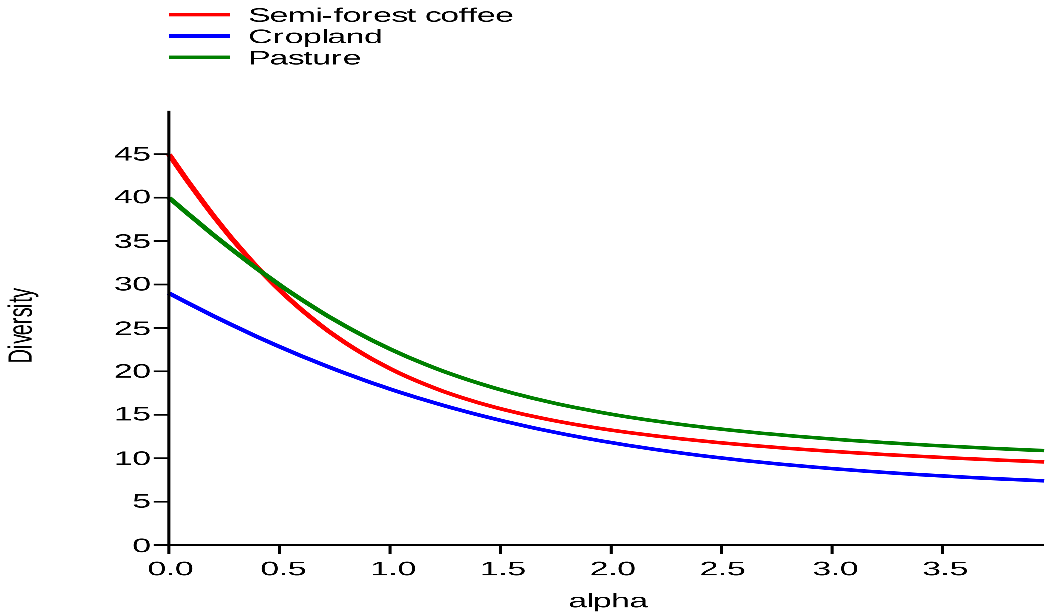

Figure 2: Diversity, richness and evenness of woody species in the study area

4.1.2.1 Shannon-Wiener diversity index

Shannon's diversity index ranges from 2.901 to 3.113 for the woody species in three land use types of the study area. Semi-forest coffee has the highest species richness, second in diversity and third in species evenness. Pasture land is relatively the most diversified one with a diversity index of 3.113 and the second in both species richness and evenness. Crop land ranked 1st in species evenness and 3rd in both diversity and species richness (Table 3)

Semi-forest coffee relatively has the highest woody species richness compared to the remaining two land use types. The high value of species richness has a great importance in keeping ecological diversity of the ecosystem. On other hands, crop land was the least in terms of its species richness.

Table 3: The value of Shannon–Wiener Diversity Index

Land use types	Species richness(S)	Diversity index(H')	H'max (LnS)	Equability(J)/ (H'/H'max)	Dominance(D)
Semi-forest coffee	45	3.011	3.81	0.452	0.0756
Pasture land	40	3.113	3.69	0.562	0.0644
Crop land	29	2.901	3.37	0.862	0.0834

4.1.2.2.Sorensen's similarity

Sorensen's similarity calculation gives the similarity between three land use types and the value were given in table 4.

Table 4 : Sorensen's similarity between different land use types in woody species

Land use types	SFC	Pasture land	Crop land
SFC	1.00	0.783	0.847
Pasture land		1.00	0.826
Crop land			1.00

4.1.2.3. Woody species structure

All individuals of woody species recorded in all plots were used in the analysis of species structure. Diameter at breast height (DBH), basal area, density, height, frequency and important value index were used for description of species structure.

4.1.2.3.1. Basal Area

The highest basal area was calculated for semi-forest coffee (49.86 m^2/ha) and the least for cropland (12.64 m^2/ha). Of the species encountered in the study area *Cordia africana* contributed the highest basal area in both semi-forest coffee and crop lands. In pasture land, *Eucalyptus camaldulensis* has contributed the highest BA/ha. The basal area of all woody species in the study area (three land use types) (Appendix- 3, 4, 5) and ten species which have largest basal area (the most important species) in each land use types were calculated and given in Table: 5, 6 and 7.

Table 5 : Basal area (BA), BA/ha, RBA of ten most important species in Semi-forest coffee.
(BA/ha = Basal area per hectare, RBA = Relative basal area)

Species name	BA	BA/ha	RBA
Cordia africana Lam.	124.18	8.87	17.79
Croton macrostachyus A.Rich	90.58	6.47	12.98
Sapium ellipticum (Krauss) Pax	67.76	4.84	9.71
Albizia gummifera (J.F. Gmel.) C.A. Sm	62.75	4.48	8.99
Millettia ferruginea (Hochst.) Bak	48.98	3.50	7.02
Ehretia cymosa Thonn.	38.73	2.77	5.55
Persea americana Mill.	37.98	2.71	5.44
Olea welwitschii (Knobl.) Gilg. & Schellenb	28.87	2.06	4.14
Vernonia amygdalina Del.	26.56	1.90	3.80
Entada abyssinica Steud.ex A.Rich	24.02	1.72	3.44

Table 6: Basal area (BA), BA/ha, RBA of ten most important species in Pasture land. (BA/ha=Basal area per hectare, RBA=Relative basal area)

Scientific name	BA	BA/ha	RBA
Eucalyptus camaldulensis Dehnh	50.39	3.599	18.51
Sapium ellipticum (Krauss) Pax	49.05	3.50	18.02
Cordia africana Lam.	40.00	2.86	14.7
Croton macrostachyus A.Rich	22.83	1.63	8.39
Acacia abyssinica Hochst ex Benth.	21.56	1.54	7.92
Ficus sur Forssk	17.56	1.25	6.45
Syzygium guineense (Wild.) DC.	15.88	1.13	5.84
Entada abyssinica Steud.ex A.Rich	9.53	0.68	3.50
Prunus africana (Hook.f) Kalkm	4.59	0.33	1.69
Olea welwitschii (Knobl.) Gilg. & Schellenb	4.43	0.32	1.63

Table 7 : Basal area (BA), BA/ha, RBA of ten most important species in crop land. (BA/ha = Basal area per hectare, RBA = Relative basal area)

Scientific name	BA	BA/ha	RBA
Cordia africana Lam.	42.08	3.01	24.07
Sapium ellipticum (Krauss) Pax	28.36	2.03	16.22
Croton macrostachyus A.Rich	21.99	1.57	12.58
Albizia gummifera (J.F. Gmel.) C.A. Sm	11.30	0.81	6.47
Eucalyptus camaldulensis Dehnh	10.28	0.73	5.88
Acacia abyssinica Hochst ex Benth.	8.79	0.63	5.03
Ficus sycomorus L.	7.00	0.50	4.01
Ficus sur Forssk.	5.38	0.38	3.08
Phoenix reclinata Jacq.	4.90	0.35	2.80
Syzygium guineense (Wild.) DC.	4.80	0.34	2.75

4.1.2.3.2. Frequency

Frequency is the number of plots in which a given species occurred in the study area. The frequency and relative frequency of all woody species in the study area were calculated. Four most frequent species in semi-forest coffee were: *Croton macrostachyus (*7.48%), *Cordia africana* (7.48%), *Millettia ferruginea (*6.80%) and *Sapium ellipticum (*6.80%*),* in pasture land: *Cordia Africana (8.60%),Sapium ellipticum* (8.60), *Croton macrostachyus* (7.53%) and *Eucalyptus camaldulensis (*7.53%) and in crop land: *Cordia Africana* (14.86%), *Sapium ellipticum (*8.11%*)*, *Croton macrostachyus* (6.76%) and *Eucalyptus camaldulensis* (5.41%) have the highest frequency value. The frequency and relative frequency of most frequent species in each land use type were calculated and recorded (Table 11, 12 and13).

4.1.2.3.3. Density

Fifty-eight woody species comprising 685 individuals with DBH ≥ 10cm and height > 2.0 m were recorded. From these, 626 (91.39%) individuals were trees and 59 (8.61%) individuals were shrubs. Out of 685 total stem count, 360 (25.71 stems/ha) were collected from semi-forest coffee, 197(14.07 stems/ha) from pasture land and 128(9.14 stems/ha) from crop lands. The result indicated that semi-forest coffee has the highest woody species density and richness than pasture and crop land which defined by their mean values ± standard error (table 9).

Table 8: Number and percentage of individual woody species collected from three land use types

Land use type	Tree		Shrubs		Total	
	Number	%	Number	%	Number	%
Semi-forest coffee	329	48.03	31	4.53	360	52.56
Pasture land	176	25.69	21	3.07	197	28.76
Crop land	121	17.66	7	0.71	128	18.69
Total	626	91.38	59	8.31	685	100

Table 9 : Mean value ± standard error of three land use types

Land use type	Density	Richness
Semi-forest coffee	25.71±1.66	10.5±0.43
Pasture land	14.07±1.69	6.93±0.56
Crop land	9.142±0.85	5.36±0.41

From the species collected, *Cordia africana* (77 stems), Millettia *ferruginea* (69 stems) and *Entada abyssinica* (58 stems) were the top three dominant tree species in the study area, while seven species (one stem each) were the least ones. From shrub species studied in the study area, *Maesa lanceolata* (23 stems) was the highest in stem count, *Morus alba* , *Euphorbia tirucalli* and *Coffea arabica each has (three stems) and Phytolacca dodecandra* represented one stem, that was the least dominant (Table.10).

Table 10 Dominant and rare woody species in the study area

Habit	Dominant species		Rare species	
	Scientific name	No	Scientific name	No
Tree	*Cordia africana* Lam	77	*Grewia ferruginea* Hochst. exA. Rich	1
	Millettia ferruginea (Hochst.) Bak	69	*Dracaena steudneri* Engl.	1
	Entada abyssinica Steud.ex A.Rich	59	*Diospyros abyssinica* (Hierm.) F. White	1
	Croton macrostahyus A.Rich	54	*Fagaropsis angolensis* (Engl.) Dale	1
	Sapium ellipticum (Krauss) Pax	54	*Polyscias fulva* (Hiern) Harms	1
	Eucalyptus camaldulensis Dehnh	37	*Casuarina equisetifolia* L	1
	Persea americana Mill	31	*Carica papaya* L	1
Shrub	*Maesa lanceolata* Forssk	23	*Rhus natalensis* Krauss	1
	Psidium guajava L	12	*Phytolacca dodecandra* L.Herit	1

The highest stem count/ha was recorded from SFC, followed by pasture land and the least from cropland (Figure 3). *Millettia ferruginea, Cordia africana, Entada abyssinica, Croton macrostachyus, Persea americana, Albizia gummifera, Sapium ellipticum, Vernonia amygdalina, Maesa lanceolata* and *Ehretia cymosa* were some of the species with relatively higher stem count/ha in the semi-forest coffee. The density and relative density of the highest stem count in all land use types were given in table 11, 12, 13.

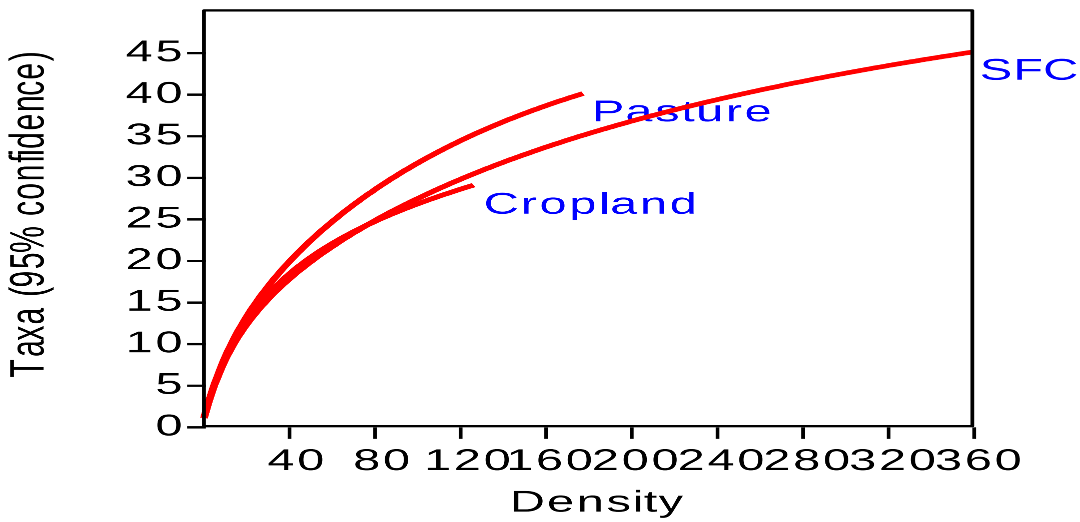

Figure 3: Density of species in each land use types

Table 11: Frequency, Relative frequency, Density and Relative density of species collected from semi-forest coffee

Semi-forest coffee(SFC)					
Species name	F	RF	D	D/he	RD
Croton macrostachyus A.Rich	11	7.48	33	2.36	9.17
Cordia africana Lam.	11	7.48	37	2.64	10.28
Millettia ferruginea (Hochst.) Bak	10	6.80	61	4.36	16.94
*Sapium ellipticum (*Krauss) Pax	10	6.80	18	1.29	5
Vernonia amygdalina Del.	8	5.44	17	1.21	4.72
Maesa lanceolata Forssk	7	4.76	14	1	3.89
Albizia gummifera (J.F. Gmel.) C.A. Sm	7	4.76	20	1.43	5.56
Entada abyssinica Steud.ex A.Rich	7	4.76	35	2.5	9.72
Olea welwitschii (Knobl.) Gilg. & Schellenb	6	4.08	6	0.43	1.67
Ehretia cymosa Thonn.	6	4.08	12	0.86	3.33

Table 12 : Frequency, Relative frequency, Density and Relative density of species collected from pasture land

Pasture land					
Scientific name	F	RF	D	D/h	RD
Cordia africana Lam.	8	8.60	12	0.86	6.74
Sapium ellipticum (Krauss) Pax	8	8.60	24	1.71	13.48
Croton macrostachyus A.Rich	7	7.53	13	0.93	7.30
Entada abyssinica Steud.ex A.Rich	6	6.45	20	1.43	11.24
Maesa lanceolata Forssk	5	5.38	9	0.64	5.06
Psidium guajava L.	3	3.23	4	0.29	2.25
Millettia ferruginea (Hochst.) Bak	2	2.15	2	0.14	1.12
Olea welwitschii (Knobl.) Gilg. & Schellenb	2	2.15	2	0.14	1.12
Celtis africana Burm.f.	2	2.15	2	0.14	1.12
Ficus sur Forssk	2	2.15	3	0.21	1.68

Table 13: Frequency, Relative frequency, Density and Relative density of species collected from crop land

Crop land					
Scientific name	F	RF	D	D/he	RD
Cordia africana Lam.	11	14.86	28	2	22.05
*Sapium ellipticum (*Krauss) Pax	6	8.11	12	0.86	9.45
Croton macrostachyus A.Rich	5	6.76	8	0.57	6.30
Millettia ferruginea (Hochst.) Bak	3	4.05	6	0.43	4.72
Psidium guajava L.	3	4.05	3	0.21	2.36
Vernonia amygdalina Del.	2	2.70	2	0.14	1.58
Vernonia auriculifera Hiern.	1	1.35	1	0.07	0.79
Ficus sur Forssk	1	1.35	1	0.07	0.79
Cupressus lusitanica Mill	1	1.35	1	0.07	0.79
Citrus sinensis (L.) Osb.	1	1.35	1	0.07	0.79

4.1.2.3.4. Importance Value Index (IVI)

Importance value index (IVI) is essential to compare the ecological importance of species in ecosystem and a key structural parameter in vegetation study. The result of IVI value calculated from RF, RD and RDM of all woody species in the study area (appendix 9.10,11) and the IVI of ten most important species in three land use types were shown in (table 14, 15, 16). The result indicated that, the most important species has the higher IVI. For example, in semi-forest coffee: *Cordia africana* (35.55), *Millettia ferruginea* (30.76), *Croton macrostachyus* (29.63), in pasture land*: Cordia africana* (30.05), *Croton macrostachyus* (23.22), *Acacia abyssinica* (22.80) and in crop land *Cordia africana* (60.68), *Sapium ellipticum* (33.58), *Croton macrostachyus* (25.48) were the important species in decreasing orders.

Table 14: Relative frequency, Relative density and Importance value index of ten most important species in semi-forest coffee

Semi-forest coffee				
Species name	RDM	RF	RD	IVI
Cordia africana Lam.	17.79	7.48	10.28	35.55
Millettia ferruginea (Hochst.) Bak	7.017	6.80	16.94	30.76
Croton macrostachyus A.Rich	12.98	7.48	9.17	29.63
*Sapium ellipticum (*Krauss) Pax	9.71	6.80	5	21.51
*Albizia gummifera (*J.F Gmel.) C.A. Sm.	8.99	4.76	5.56	19.31
Entada abyssinica Steud.ex A.Rich	3.44	4.76	9.72	17.93
Persea americana Mill.	5.44	4.08	7.5	17.02
Vernonia amygdalina Del.	3.80	5.44	4.72	13.97
Ehretia cymosa Thonn.	5.55	4.08	3.33	12.96
Maesa lanceolata Forssk	1.55	4.76	3.89	10.2

Table 15: Relative frequency, Relative density and Important Value Index of ten most important species in pasture land

Pasture land				
Scientific name	RDM	RF	RD	IVI
*Sapium ellipticum (*Krauss) Pax	18.03	8.60	13.48	40.11
Eucalyptus camaldulensis Dehnh	18.52	7.53	13.48	39.53
Cordia africana Lam.	14.7	8.60	6.74	30.05
Croton macrostachyus A.Rich	8.39	7.53	7.30	23.22
Acacia abyssinica Hochst ex Benth.	7.93	6.45	8.43	22.8
Entada abyssinica Steud.ex A.Rich	3.50	6.45	11.24	21.19
Syzygium guineense (Wild.) DC.	5.84	3.23	6.18	15.24
Maesa lanceolata Forssk	0.61	5.38	5.06	11.04
Flacourtia indica (Brm.f.) Merr	1.32	5.38	3.93	10.63
Ficus sur Forssk	6.45	2.15	1.69	10.29

Table 16: Relative frequency, Relative density and Important Value Index of ten most important species in crop land

Crop land				
Scientific name	RDM	RF	RD	IVI
Cordia africana L Lam.	23.77	14.86	22.05	60.68
Sapium ellipticum (Krauss) Pax	16.02	8.11	9.45	33.58
Croton macrostachyus A.Rich	12.42	6.76	6.30	25.48
Eucalyptus camaldulensis Dehnh	5.81	5.41	6.30	17.51
Acacia abyssinica Hochst ex Benth.	4.96	4.05	5.51	14.53
Albizia gummifera (J.F. Gmel.) C.A. Sm	6.39	4.05	3.94	14.38
Erythrina abyssinica Lam. Ex Dc.	2.05	5.41	5.51	12.97
Phoenix reclinata Jacq.	2.77	4.05	5.51	12.33
Millettia ferruginea (Hochst.) Bak	2.69	4.05	4.72	11.47
Syzygium guineense (Wild.) DC.	2.71	2.70	3.94	9.35

4.1.2.3.5. Tree height

Out of 360 total trees density recorded in SFC, 32 (8.89%) stem count found in lower storey (height <10.33), 229 (63.61%) stem count found in middle storey (height, 10.33-20.67) and 99 (27.50%) stem count found in upper storey (height >20.67). In general, the density of woody species in lower, middle and upper storey was found to be 2.29 density/ha, 16.36 density/ha and 7.07 density/ha respectively.

4.1.3. Comparison of semi-forest coffee with other land use types

The density (stem count) of woody species in three land use types was checked for variation between three land use types. Significant statistical difference (F = 34.21, P = 0) in woody species density was observed among the three land use types (table 17). Tukey's multiple comparison also showed the variation between each land use types (Table 18). Prior to this test, the data were check for normality distribution using Shapiro-Wilk normality test. Homogenous subsets displayed show that crop land with pasture land was more related in terms of species density and richness than within between other lands uses (table 19).

Table 17: Summary of value of significance for one -way ANNOVA between the three land use types for density

Density/ha	SS	df	MS	F	p
Between Groups	2027.48	2	1013.74	34.21	0.00
Within Groups	1155.5	39	29.63		
Total	3182.98	41			

Table 18: Summary of ANNOVA for variation of density between each land use types.

(I) Land use types	(J)Land use types	Mean Difference (I-J)	S.E	p	95% Confidence Interval	
					Lower Bound	Upper Bound
SFC	Cropland	16.58	2.057	0.00	11.56	21.58
SFC	Pasture	11.64	2.057	0.00	6.63	16.66
Pasture	Cropland	4.93	2.057	0.055	-0.08	9.94

Table 19: Homogeneous subset

Land use types	N	Subset for alpha = 0.05	
		1	2
Cropland	14	9.14	
Pasture	14	14.07	
SFC	14		25.71

Sig.		0.055	1.00

4.1.4. Abovegroud live biomass and carbon storage across three land use types in Shabe Sombo District

The aboveground live biomass and stored carbon in woody species of different land use types was calculated (Table 20).

4.1.4.1. Aboveground live carbon storage in semi-forest coffee

The aboveground biomass of woody species in semi-forest coffee was 41.60 t/ha and the total stored AGC was 20.79 t/ha. The minimum (0.97 t/ha) and maximum (2.18 t/ha) AGC was estimated in the region of plot two and nine respectively. The amount of CO_2 sequestered in semi-forest coffee was 76.3 t/ha.

4.1.4.2. Aboveground live carbon storage in pasture lands

The amount of aboveground live biomass calculated from pasture land was 14.57 t/ha and the amount of AGC stored was 6.73 t/ha. The minimum (0.12 t/ha) and maximum (0.9 t/ha) AGC was stored in plot 3 and 2 respectively. The amount of CO_2 sequestered in this land use type was 24.69 t/ha.

4.1.4.3 Aboveground live carbon storage in crop lands

The amount of aboveground live biomass in croplands was 8.05 t/ha from which 4.28 t/ha AGC was calculated. The minimum (0.06 t/ha) and maximum (0.48 t/ha) value of AGC was stored. The estimated CO_2 sequestered by the scattered trees in the cropland was 15.7 t/ha.

4.1.4.4. Total AGB and AGC in the study area

AGB and AGC of the study area were calculated by summing all the value in each land use type, which was for aboveground woody species (table-20)

Table 20: Summary of AGB .AGC and $AGCO_2$ in different land use types

Land use types	AGB t/ha	AGC t/ha	$AGCO_2$ t/ha
Semi-forest coffee	41.6	20.79	76.30
Pasture land	14.57	6.73	24.70
Crop land	8.05	4.28	15.71
Total	64.22	31.8	116.71

4.1.4.5. Comparison of AGC at different land use types

The difference among the three land use types in aboveground live carbon storage was conducted using one way analysis of variance (ANOVA) (Table 21). Significant statistical difference ($F = 202.06$, $P = 0$) within land use types was observed. Shapiro-Wilk normality test was computed to check the assumption of normal distribution ($W = 0.9583$, $P = 0.6945$). Tukey's multiple comparison computed and the variation between each land use types was showed in (Table 22). The homogeneous subset also showed that crop land and pasture were closely related (Table 23).

Table 21: Summary of values of significance for one-way ANOVA between the different land use types for AGC

AGC (t/ha)	SS	df	MS	F	P
Between Groups	2223.3	2	1111.65	102.06	0.00
Within Groups	424.81	39	10.89		

Total	2648.11	41

Table 22: Summary of ANNOVA for comparison of AGC among land use types

(I)Land use types	(J)Land use types	Mean Difference (I-J)	S.E	P	95% Confidence Interval	
					Lower	Upper
SFC	Cropland	16.51	1.25	0	13.47	19.55
SFC	Pasture	14.06	1.25	0	11.02	17.10
Pasture	Cropland	2.45	1.25	0.14	-0.59	5.49

Table 23: Homogenous subset within different land use for AGC (t/ha)

Land use types	N	Subset for alpha = 0.05	
		1	2
Cropland	14	4.2785	
Pasture	14	6.7294	
SFC	14		20.7913
Sig.		0.135	1

4.1.4.6. Carbon store variation among tree and shrubs species

Out of the total AGC estimated in the study area, the highest amount was contributed by tree species (30.1 t/ha) while the least was contributed by shrubs species (1 t/ha).

4.1.4.7. Carbon store variation among different woody species

The amount of AGC varies from species to species. *Cordia africana* has the highest AGC (1.67t/ha) followed by *Sapium ellipticum (*1.28t/ha). In contrast, *Rhus natalensis (*0.001 t/ha) and *Premna schimperi (*0.004t/ha) stored the least AGC compared to all other woody species in the study area. Among the woody species in the study area, ten were found with relatively higher AGC compared to other species (Table 24).

Table 24 : Biomass and AGC in ten woody species in the study area

Scientific name	AGBt/ha	AGCt/ha	$AGCO_2$t/ha
Cordia africana Lam	3.34	1.67	6.13
*Sapium ellipticum (*Krauss) Pax	2.56	1.28	4.70
Croton macrostachyus A.Rich	2.26	1.13	4.15
Eucalyptus camaldulensis Dehnh	1.54	0.77	2.83
Albizia gumnifera (J.F. Gmel.) C.A. Sm	1.3	0.65	2.39
Persea americana Mill.	1.18	0.59	2.17
Millettia ferruginea (Hochst.) Bak	1.12	0.56	2.06
Acacia abyssinica Hochst ex Benth.	0.82	0.41	1.50
Ehretia cymosa Thonn.	0.54	0.27	0.99
Entada abyssinica Steud.ex A.Rich	0.48	0.24	0.88

4.2. Discussion

4.2.1. Woody species composition

In this study, Fabaceae is the most species rich family. Similar result has been reported from Jimma Highland by Kfley Gebrehiwot and Kitessa Hundara (2011) and from Dello Menna, southeast Ethiopia by Motuma Didita *et al*. (2010). Compared to Abiot Molla and Gonfa Kewessa (2015), Etefa Guyassa and Rej (2013), Belay Tefera *et al.* (2014) the woody species abundance in the study area was high, while it was lower in Beseku (Tolera Motuma *et al.*, 2008), in Sidama (Tesfaye Abebe, 2005), in Nicaragua (Mendez, 2001), in Welo (Getachew Tadesse *et al*..2008). The variation in woody species richness could be due to management strategy, socioeconomic factors and farmers' preferences for tree species and functions in different localities. For example, in the present study area, farmers maintained many tree species for coffee shade, and edible fruits.

In particular, the highest number of woody species was recorded in semi-forest coffee as compared to crop and grazing lands. The possible explanation for this is that, farmers normally conserve woody species in their coffee forests, because coffee cultivation needs the shade of woody plants. Tree species with flat and wider canopies are favored by the coffee growers for shade provision, and the coffee shrubs/trees are believed to give better yield under the canopy of these trees (Diriba Muleta *et al*. 2011). The farmers' choice for coffee shade trees was in line with the abundance of tree species in the coffee lands. Out of the total 685 individual trees recorded in the study area, 360 stems were from SFC. Of these, the species with large number of stem count *Millettia ferruginea, Albizia gummifera* and *Entada abyssinica* were from the same plant family (Fabaceae). In addition to shade provision for coffee shrubs/trees, these species have natural capacity for nitrogen fixation, due to symbiotic associations between their roots and rhizobia, improving soil fertility for the coffee shrubs (Dereje Denu *et al.,* 2016). Shade trees provide a range of benefits to coffee plants including reduction of air and soil temperature extremes and reduction in the quantity and quality of transmitted light and hence avoidance of overbearing (Beer *et al*., 1998; Bote and Struik, 2011, cited in Kitesa Hundera, 2015).

*Millettia ferruginea (*4.36 stems/ha) and *Cordia Africana (*2.64 stems/ha) were the most abundant and top preferred shade trees in SFC, these was also reported by Dereje Denu *et al*. (2016). Compared to Dereje Denu *et al.* (2016), the stem count/ha in the current study was much smaller. This might be due to the use of *Cordia africana* for timber production. The number of woody species recorded from crop and pasture land in this study was relatively high compared to the similar study conducted in Tigray region (Etefa Guyassa and Rej, 2013) and in Debark District, northern Ethiopia (Belay Tefera *et al.*, 2014).

The current study showed the reduction of woody species richness in cropland. This could be due to the management of farmland by the farmers to reduce the effect of shade and competition with their crop. This result is also similar with the findings reported by Bobo (2006) from Cameroon. In the study area only *Cordia africana* has high abundance in crop land mainly due to its valuable timber. Pasture land was characterized by high diversity index because of the culture of maintaining several tree species in the pasture lands by the local community. The number of shrub species in the study area was very small compared to tree species because people do not maintain them in croplands and semi-forest coffee plots.

4.2.2. Woody species diversity, richness and evenness

Shannon diversity index (H), Shannon equitability/evenness index (E), species richness (S), diversity profile (figure.2) and these showed that the crop land had the highest evenness index and semi-forest coffee had the least evenness index. Semi-forest coffee showed the highest species richness followed by pasture land. Similar finding has been reported by Etefa Guyassa and Rej (2013) in which crop land showed the least species diversity. Compared to Etefa Guyassa and Rej (2013), the species diversity in our pasture land had relatively higher species diversity. The study conducted on Borana woodlands (Adefires Worku, 2006) also had less species richness and diversity compared to the present study. .

The high Shannon diversity index indicated that the land use had relatively higher average number of woody species as compared to other land use types and high evenness described species were equally distributed within the areas. The low value of Shannon evenness index indicated that, the dominance by a single or few species. High value of richness indicated, high number of species. The probable causes for the variability of each value for the different land use types arise from extent of disturbance (way of local people to ward coffee cultivation, timber and charcoal production activity) and other environmental factors (like slope and soil) which were not included in this study.

Basal area

Cordia africana was the most important woody species in the study area in having large basal area ($4.82m^2$/ha) followed by *Sapium ellipticum* ($3.46m^2$ /ha) and *Croton macrostachyus* ($3.23m^2$/ha) due to higher DBH value. The result showed that woody species in semi-forest coffee had the highest basal area followed by pasture land, while the basal area in crop land was the least. Therefore, plants in semi-forest coffee relatively had more basal area than other land use types. This might be because of the age of trees (usually they are maintained for many years) and relatively higher number of stems (density/ha) and the conservation of the shade trees for shade provision. The total basal area of woody species in this study was higher than what was reported by Yemenzwork Endale (2004) in East Showa Zone (basal area of $2.2m^2$/ha) and lower than what was reported from Metema area by Haile Adamu *et al*. (2012) and from Gedo (Brihanu Kebede *et at*., 2014)

Wood density

The largest stem count/ha in semi-forest coffee 61(4.36/ha) was contributed by *Millettia ferruginea*. It is one of the most important coffee shade trees in the study area and that was why the coffee growers maintain it in their coffee plots. This agrees with the result of Dereje Denu *et al.* (2016) and Diriba Mulleta *et al*. (2011). The second woody species with higher stem count/ha was *Cordia africana.* This tree species has been conserved by the community in Shabe Sombo for its importance in providing shade for the coffee shrubs beneath the canopy and also for its use as a source of quality timber. This also agrees with the findings of Dereje Denu *et al.* (2016) and Diriba Mulleta *et al.* (2011). As the information obtained from the local community shows, there is a culture of replacing (planting or growing seedlings) before cutting down the old *C.africana* trees for timber.

In contrast, low density/ha was observed in crop land may be to increase crop production and reduce competition of woody species with crops for resources. Some trees in crop lands with large canopies could have a negative impact on crop production (Yemenzwork Endale *et al*., 2017). Pasture land is in the second position in terms of stem density/ha following semi-forest coffee system. The stem count in pasture land is not as high as in semi-forest coffee, most probably due to grazing and browsing pressure and cutting of trees for firewood and charcoal production.

The density values of this study (685 stem/ha) is comparable with the results of Ahmed Bashir (2003) who reported an average total density of 373 stems/ha in his vegetation study of Harshin Wereda in Jig-jiga Zone and lower than what was reported by Mohammed Omer (2011) who reported the total density of 1037 and 722 stems /ha at different land use types in Awbare wereda, Jig-jiga.

Frequency

The frequency analyses showed that, most of the studied species were in more or less good distribution across the land use types. The coffee shade trees got a chance of occurring more frequently. In contrast, most species in crop lands were less frequent.

Cordia africana was the species with the highest frequency of occurrence relative frequency value of (9.84%) followed by *Croton macrostachyus* relative frequency value of (7.54%). About 13 species with lowest frequency of occurrence relative frequency value (0.33%). The remaining species occurred between the above values which were in lower frequency class. These showed large number of species in lower frequency class and small number of species in higher frequency class, which indicates high heterogeneity of woody species in the study area. Similar result was reported from East Shewa Zone (Yemanzework Endale, 2014)

Important Value Index

The most important species in the study area showed the high value of IVI. This is mostly for their high dominance and density which may be due to their low demand by local community for timber (*Millettia ferruginea*, *Croton macrostachyus*, *Sapium ellipticum*, *Entada abyssinica*, *Persea americana*, *Vernonia amygdalina*, *Ehretia cymosa*), and their contribution of large basal area (*Cordia africana*, *Ficus sur*, *Albizia gummifera*). Related result was reported from Belete forest, the nearest to current study area (Kfley Gebrehiwot and Kitessa Hundara, 2011).

Height

The result showed that, high number of stem count in semi-forest coffee was found in the middle storey (between 10.33m and 20.67m). This indicates that there were no more trees found in lower and upper storey (< 10.33m and > 20.67m). This may be due to human pressure on the trees in the lower and upper storeys.

4.2.3. Biomass and carbon storage

The AGB (64.22 t/ha), AGC (31.8 t/ha and $AGCO_2$ (116.71 t/ha) had been calculated in the study area. Large amount of these value were contributed by semi-forest coffee and low value observed in crop land. The probable reasons for variability of carbon storage were: woody species density, woody species richness, variation of woody species, tree size (height and DBH) and ways of use by local people.

The variation in AGC among three land use types was also analyzed by one way ANOVA. The result showed that, there was significant statistical difference in carbon storage between SFC and crop land as well as between SFC and pasture land ($p<0.05$), but variation between pasture and crop lands was not significant ($p>0.05$) (Table 24). SFC (20.79±1.21SE) stored significantly more AGC than pasture land (6.73±0.8SE) and cropland (4.28±0.46SE). This result was less than the finding of Dereje Denu (2016) who reported (61.5±25.0) for SFC and higher than (2.5± 2.7) for pasture land (2.0±0.8) for crop land.

The important reason for the variation of carbon storage in different land use types was species richness. In the study area, species richness of semi-forest coffee was greater than that of pasture land and crop lands. Ruiz-Jaen *et al*. (2011) also found that carbon storage and biomass increase with increase in species richness. The variation of AGC explained by stem count was not statistically significant.

Cordia africana was the species with the highest carbon storage in the study area. The species has been conserved for coffee shade and timber production in the study area. This might be the reason for the larger AGC storage in its biomass. This was larger than the findings of Hamere Yohannes *et al*. (2015) in which 0.37t/ha carbon was reported in *Cordia africana*. The species also contributed more carbon storage in semi-forest coffee than in other land use types .In other ways, *Rhus natalensis* was one of the least contributors to carbon storage in the study area. Small DBH and short height, harvesting for fire wood might be the probable reason for the species to contribute least to carbon storage in the study area. Acording to Hamere Yohannes *et al*. (2015) dominant species have more DBH and height mean value and contribute more total carbon storage.

Carbon storage variation among plant habit

Only 1t/ha of AGC stored in shrubs in the study area. This is for the reason that, density, richness, height and DBH of individual shrub species recorded in the study were lower than that of tree species. The larger diameter class stored a large stock of AGB; whereas a small amount of AGB has been stocked by small diameter class **(**Talemos Seta and Sebsebe Demissew, 2014). Other cause may be, shrubs removed for fire wood, not allowed to grow in coffee plants and they cannot resistance to animal disturbance. Similar result was reported from West Arsi Zone (Muluken Nega, 2014): 0.27 t/ha total AGC stored in shrubs of the study area.

Table 25 : Comparison of carbon storage in current study with others related studies

Study site	Source	TAGC t/ha
Wenago district, Ethiopia	Talemos Seta and Sebsebe Demissew, 2014	16.66
Selected church forest in Addis Ababa	Tulu Tolla, 2011	128.86
Central Closed Public Park in Addis Ababa	Mareshet Tefera,2013	29.1
Sub-Saharan Africa	Unruh *et al*., 1993	4.5 to 19
Shabe Sombo	Current study	31.08

CHAPTER FIVE

5. Conclusion and recommendation

5.1. Conclusion

The study was conducted in Shabe Sombo district, Jimma Zone for assessing woody species diversity and aboveground live carbon storage in three land use types. Fifty eight woody species belong to 53 genera and 33 families were collected and identified. The family Fabaceae was the most dominant with seven species and seven genera followed by Euphorbiaceae and Moraceae each with five species and four genera.

There were 685 individual trees recorded in the study area. Out of these, 360 stems were in semi-forest coffee, 197 in pasture land and 128 stems in crop land. Diversity analysis indicated highest species richness in semi-forest coffee, highest species diversity in pasture land and highest evenness in crop lands. Most of the stems recorded were trees (626 stems) and few stems were shrubs (59 stems).

The highest aboveground biomass carbon storage was observed in semi-forest coffee and low in pasture and crop lands. Farmers give priority for woody species in semi-forest coffee for shade provision. The Traditional coffee management practice in the study area could help in CO_2 sequestration, one of the climate change mitigation options. The amount of carbon stored in aboveground live woody biomass varies from species to species. *Cordia africana* ranked first in the amount of carbon stored in its biomass.

The study provides two important points: Investigating woody species diversity outside of forest ecosystem and estimating abocground live biomass carbon storage of woody species in difference land use types of the study area.

5.2. Recommendation

Based on the finding of this study the following recommendations are forwarded

1. The woody species in agricultural landscapes stored relatively higher aboveground live carbon which could help in climate change mitigation. Because of the current forest degradation and GHG upgrading, expanded climate change suffer the whole countries including the study areas, therefore, paying equal attention to woody species in agricultural land as to forest is a better solution in reducing carbon emission.
2. Developing ways of maximizing trees on pasture and crop lands are important to enhance carbon storage in the aboveground live biomass without compromising the yield on the cropland.
3. Creating public and other stakeholders' awareness about the importance of on farm woody species in biodiversity conservation and carbon storage.
4. Farm lands could be seen as gene bank of indigenous plants which have been lost from the wild, so conservation of plants in agricultural fields could be the right direction to restore our native plant species.
5. This study could be used as a base line for further study on carbon storage and biodiversity conservation in agricultural land
6. This study did not address other carbon pools including the soil carbon. Therefore, we recommend further research to be carried out to fill the gaps indicated by this study.

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Appendixes

Appendix 1: List of species collected from the study area, (A/O=Afan Oromo, Ha=Habit)

No	Scientific name	Local name (A/O)	Family	Ha
1	*Acacia abyssinica* Hochst ex Benth.	Laaftoo	Fabaceae	T
2	*Albizia gummifera* (J.F. Gmel.) C.A. Sm	Hambabeessa	Fabaceae	T
3	*Annona senegalensis* Pers,	Giishxaa	Annonaceae	T
4	*Bersama abyssinica* Fresen	Lolchiisaa	Melianthaceae	T
5	*Carica papaya* L.	Paappayaa	Caricaceae	T
6	*Casuarina equisetifolia* L.	Shuwaashuwee	Casuarinaceae	T
7	*Celtis africana* Burm.f.	Qahee	Ulmaceae	T
8	*Citrus sinensis* (L.) Osb.	Burtukaana	Rutaceae	T
9	*Clausena anisata* (Wild.) Hook. F.ex.Benth	Ulmaayii	Rutaceae	S
10	*Coffea arabica* L.	Buna	Rubiaceae	S
11	*Combretum paniculatum* Vent	Dhandheessaa	Combretaceae	T
12	*Cordia africana* Lam.	Waddessa	Boraginaceae	T
13	*Croton macrostachyus* A.Rich	Bakkanisa	Euphorbiaceae	T
14	*Cupressus lusitanica* Mill.	Gaattiraa	Cupressaceae	T
15	*Diospyros abyssinica* (Hierm.) F. White	Lookoo	Ebenaceae	T
16	*Dracaena steudneri* Engl.	Emoo	Dracaenaceae	T
17	*Ehretia cymosa* Thonn.	Ulaagaa	Boraginaceae	T
18	*Ekebergia capensis* Sparm.	Somboo	Meliaceae	T
19	*Entada abyssinica* Steud.ex A.Rich	Ambaltaa	Fabaceae	T
20	*Erythrina abyssinica* Lam.ex Dc.	Waleensuu	Fabaceae	T
21	*Eucalyptus camaldulensis* Dehnh	Baargamoo diimaa	Myrtaceae	T
22	*Eucalyptus globulus* Labill.	Baargamoo adii	Myrtaceae	T
23	*Euphorbia abyssinica* Gmel.	Adaammii	Euphorbiaceae	T
24	*Euphorbia tirucalli* L.	Cadaa	Euphorbiaceae	S
25	*Fagaropsis angolensis* (Engl.) Dale	Sigluu	Rutaceae	T
26	*Ficus sur* Forssk.	Harbuu	Moraceae	T

27	*Ficus sycomorus* L.	Odaa	Moraceae	T
28	*Ficus thonningii* Blume	Dambii	Moraceae	T
29	*Ficus vasta* Forssk	Qilxuu	Moraceae	T
30	*Flacourtia indica* (Brm.f.) Merr	Akuukkuu	Flacourtiaceae	T
31	*Olea capensis* L.	-	Oleaceae	T
32	*Gardenia ternifolia* Schumach&Thonn.	Qambeelloo	Rubiaceae	T
33	*Grevillea robusta* R. Br.	Giraavilaa	Proteaceae	T
34	*Grewia ferruginea* Hochst. exA. Rich.	Dhoqonuu	Tiliaceae	T
35	*Maesa lanceolata* Forssk	Abbayyii	Myrsinaceae	S
36	*Mangifera indica* L.	Maangoo	Anacardiacea e	T
37	*Maytenus arbutifolia* (A. Rich.) Wilczek	Kombolcha	Celastraceae	S
38	*Millettia ferruginea* (Hochst.) Bak	Askira	Fabaceae	T
39	*Morus alba* L.	Goraa faranjii	Moraceae	T
40	*Olea welwitschii* (Knobl.) Gilg. & Schellenb	Bayaa	Oleaceae	T
41	*Persea americana* Mill.	Avokaadoo	Lauraceae	T
42	*Phoenix reclinata* Jacq.	Meexxii	Arecaceae	T
43	*Phytolacca dodecandra* L.Herit.	Andoodee	Phytolaccaceae	S
44	*Piliostigma thonningii* (Schum.)	Liilluu	Fabacea	T
45	*Pittosporum viridiflorum* Sims	Shoolee(Soolee)	Pittosporaceae	T
46	*Polyscias fulva* (Hiern) Harms	Kariyoo	Araliaceae	T
47	*Premna schimperi* Engi.	Urgeessaa	Lamiacea	S
48	*Prunus africana* (Hook.f) Kalkm	Oomoo(Hoomii)	Rosaceae	T
49	*Psidium guajava* L.	Shafaafee	Myrtaceae	S
50	*Terminalia schimperiana* Hochst.	Dabbaqqaa	Combretaceae	T
51	*Rhus natalensis* Krauss	Xaaxessaa	Anacardiaceae	S
52	*Ricinus communis* L.	Qobboo	Euphorbiaceae	T
53	*Sapium ellipticum* (Krauss) Pax	Bosoqa	Euphorbiaceae	T
54	*Sesbania sesban* (L.) Merr.	Tasbaniyaa	Fabaceae	T
55	*Spathodea campanulata* P.Beanv	Anuunuu	Bignoniaceae	T

56	*Syzygium guineense* (Wild.) DC.	Baddeessaa	Myrtaceae	T
57	*Vernonia amygdalina* Del.	Dheebich	Asteraceae	S
58	*Vernonia auriculifera* Hiern.	Reenjii	Asteraceae	S

Appendix 2: Family, genus, species and their percentage of plant collected from the study area.

Family Name	No of Genera	%	No of species	%
Anacardiaceae	2	3.78	3	5.17
Annonaceae	1	1.89	1	1.72
Araliaceae	1	1.89	1	1.72
Arecaceae	1	1.89	1	1.72
Asteraceae	1	1.89	2	3.45
Bignoniaceae	1	1.89	1	1.72
Boraginaceae	2	3.77	2	3.45
Caricaceae	1	1.89	1	1.72
Casuarinaceae	1	1.89	1	1.72
Celastraceae	1	1.89	1	1.72
Combretaceae	1	1.89	1	1.72
Cupressaceae	1	1.89	1	1.72
Dracaenaceae	1	1.89	1	1.72
Ebenaceae	1	1.89	1	1.72
Euphorbiaceae	4	7.55	5	8.62
Fabaceae	7	13.21	7	12.07
Flacourtiaceae	1	1.89	1	1.72
Lamiacea	1	1.89	1	1.72
Lauraceae	1	1.89	1	1.72
Meliaceae	1	1.89	1	1.72
Melianthaceae	1	1.89	1	1.72
Moraceae	4	7.55	5	8.62
Myrsinaceae	1	1.89	1	1.72

Myrtaceae	3	5.66	4	6.98
Oleaceae	1	1.89	1	1.72
Phytolaccaceae	1	1.89	1	1.72
Pittosporaceae	1	1.89	1	1.72
Proteaceae	1	1.89	1	1.72
Rosaceae	1	1.89	1	1.72
Rubiaceae	3	5.66	3	5.17
Rutaceae	3	5.66	3	5.17
Tiliaceae	1	1.88	1	1.72
Ulmaceae	1	1.89	1	1.72
33	53	100	58	100

Appendix 3: Basal area, BA/ha and relative basal area in semi-forest coffee

Species name	BA	BA/ha	RBA
Cordia africana Lam.	124.18	8.87	17.79
Croton macrostachyus A.Rich	90.58	6.47	12.98
Sapium ellipticum (Krauss) Pax	67.76	4.84	9.71
Albizia gummifera (J.F. Gmel.) C.A. Sm	62.75	4.48	8.99
Millettia ferruginea (Hochst.) Bak	48.98	3.49	7.02
Ehretia cymosa Thonn.	38.73	2.77	5.55
Persea americana Mill.	37.98	2.71	5.44
Olea welwitschii (Knobl.) Gilg. & Schellenb	28.87	2.06	4.14
Vernonia amygdalina Del.	26.56	1.89	3.80
Entada abyssinica Steud.ex A.Rich	24.02	1.72	3.44
Erythrina abyssinica Lam.ex Dc.	17.33	1.24	2.48
Prunus africana (Hook.f) Kalkm	11.78	0.84	1.69
Maesa lanceolata Forssk	10.81	0.77	1.55
Ficus thonningii Blume	10.09	0.72	1.44
Eucalyptus camaldulensis Dehnh	8.44	0.60	1.21
Euphorbia abyssinica Gmel.	7.97	0.57	1.14

Acacia abyssinica Hochst ex Benth.	7.94	0.57	1.14
Syzygium guineense (Wild.) DC.	7.89	0.56	1.13
Spathodea campanulata P.Beanv	7.73	0.55	1.12
Ekebergia capensis Sparm.	7.47	0.53	1.07
Ficus vasta Forssk	7.17	0.51	1.03
Psidium guajava L.	6.32	0.45	0.90
Annona senegalensis Pers,	4.83	0.35	0.69
Ficus sur Forssk	4.47	0.32	0.64
Eucalyptus globulus Labill.	2.89	0.22	0.41
Bersama abyssinica Fresen	2.84	0.20	0.41
Rhus natalensis Krauss	2.58	0.18	0.37
Flacourtia indica (Brm.f.) Merr	2.44	0.17	0.35
Vernonia auriculifera Hiern.	2.12	0.15	0.30
Grevillea robusta R. Br.	1.97	0.14	0.28
Carica papaya L.	1.94	0.14	0.28
Euphorbia tirucalli L.	1.35	0.09	0.19
Fagaropsis angolensis (Engl.) Dale	1.26	0.09	0.18
Maytenus arbutiolia (A. Rich.) Wilczek	1.12	0.08	0.16
Celtis africana Burm.f.	0.96	0.07	0.14
Dracaena steudneri Engl.	0.79	0.06	0.11
Combretum paniculatum Vent	0.78	0.06	0.11
Pittosporum viridiflorum Sims	0.77	0.05	0.11
Gardenia ternifolia Schumach&Thonn.	0.75	0.05	0.11
Grewia ferruginea Hochst. exA. Rich	0.75	0.05	0.11
Mangifera indica L.	0.60	0.04	0.09
Clausena anisata (Wild.) Hook. F.ex.Benth	0.48	0.03	0.07
Citrus sinensis (L.) Osb.	0.45	0.03	0.06
Coffea arabica L.	0.27	0.02	0.04
Phoenix reclinata Jacq.	0.23	0.02	0.03
Total	698.00	49.86	100

Appendix 4: Basal area, BA/ha and relative basal area in pasture land

Pasture land			
Scientific name	BA	BA/ha	RBA
Eucalyptus camaldulensis Dehnh	50.39	3.59	18.51
*Sapium ellipticum (*Krauss) Pax	49.05	3.50	18.02
Cordia africana Lam.	40.01	2.86	14.7
Croton macrostachyus A.Rich	22.83	1.63	8.39
Acacia abyssinica Hochst ex Benth.	21.56	1.54	7.92
Ficus sur Forssk	17.56	1.25	6.45
Syzygium guineense (Wild.) DC.	15.88	1.13	5.835
Entada abyssinica Steud.ex A.Rich	9.53	0.68	3.50
Prunus africana (Hook.f) Kalkm	4.59	0.33	1.69
Olea welwitschii (Knobl.) Gilg. & Schellenb	4.43	0.32	1.63
Ficus sycomorus L.	4.21	0.30	1.55
Ficus vasta Forssk	4.15	0.29	1.52
Flacourtia indica (Brm.f.) Merr	3.59	0.26	1.32
Cupressus lusitanica Mill	2.39	0.17	0.88
Euphorbia abyssinica Gmel.	2.16	0.15	0.79
Phoenix reclinata Jacq.	2.11	0.15	0.78
Millettia ferruginea (Hochst.) Bak	1.84	0.13	0.68
Maesa lanceolata Forssk	1.65	0.12	0.61
Bersama abyssinica Fresen	1.54	0.11	0.56
Piliostigma thonningii (Schum.)	1.54	0.11	0.56
Ficus thonningii Blume	1.15	0.08	0.42
Albizia gummifera (J.F. Gmel.) C.A. Sm	1.07	0.08	0.39
Combretum paniculatum Vent	1.03	0.07	0.38
Olea capensis L.	0.99	0.07	0.36
Morus alba L	0.86	0.06	0.32
Rhus natalensis Krauss	0.79	0.07	0.29
Polyscias fulva (Hiern) Harms	0.75	0.05	0.28
Ehretia cymosa Thonn.	0.68	0.045	0.25
Psidium guajava L.	0.67	0.05	0.25

Erythrina abyssinica Lam.ex Dc.	0.63	0.05	0.23
Diospyros abyssinica (Hierm.) F. White	0.48	0.03	0.18
Sesbania sesban (L.) Merr.	0.43	0.03	0.16
Casuarina equisetifolia L	0.31	0.02	0.11
Grevillea robusta R. Br.	0.29	0.02	0.11
Grewia ferruginea Hochst. exA. Rich.	0.29	0.02	0.11
Phytolacca dodecandra L.Herit.	0.19	0.01	0.07
Rhus natalensis Krauss	0.18	0.01	0.07
Pittosporum viridiflorum Sims	0.16	0.01	0.06
Premna schimperi Engi.	0.13	0.01	0.05
Vernonia auriculifera Hiern.	0.13	0.01	0.05
Total	272.21	19.44	100

Appendix 5: Basal area, BA/ha and relative basal area in crop land.

Scientific name	BA	BA/ha	RBA
Cordia africana Lam.	42.08	3.01	23.77
Sapium ellipticum (Krauss) Pax	28.36	2.03	16.02
Croton macrostachyus A.Rich	21.99	1.57	12.42
Albizia gummifera (J.F. Gmel.) C.A. Sm	11.30	0.81	6.39
Eucalyptus camaldulensis Dehnh	10.28	0.73	5.81
Acacia abyssinica Hochst ex Benth.	8.79	0.63	4.96
Ficus sycomorus L.	7.00	0.50	3.96
Ficus sur Forssk	5.38	0.38	3.04
Phoenix reclinata Jacq.	4.89	0.35	2.77
*Syzygium guineense (*Wild.) DC.	4.79	0.34	2.71
*Millettia ferruginea (*Hochst.) Bak	4.76	0.34	2.69
Entada abyssinica Steud.ex A.Rich	4.57	0.33	2.58
Erythrina abyssinica Lam.ex Dc	3.64	0.26	2.05
Gardenia ternifolia Schumach&Thonn.	2.58	0.18	1.46
Ehretia cymosa Thonn.	2.46	0.18	1.39
Mangifera indica L	2.18	0.16	1.23

Eucalyptus globulus Labill.	1.86	0.13	1.05
Ficus vasta Forssk	1.69	0.12	0.96
Persea americana Mill.	1.52	0.11	0.86
Psidium guajava L.	1.45	0.10	0.82
Vernonia amygdalina Del.	1.44	0.10	0.81
Euphorbia abyssinica Gmel.	0.83	0.06	0.47
Annona senegalensis Pers,	0.78	0.06	0.44
Cupressus lusitanica Mill	0.77	0.05	0.43
Sesbania sesban (L.) Merr.	0.48	0.03	0.27
Euphorbia tirucalli L.	0.39	0.03	0.22
Ricinus communis L.	0.34	0.02	0.19
*Citrus sinensis (*L.) Osb.	0.24	0.02	0.14
Vernonia auriculifera Hiern.	0.16	0.01	0.09
Total	177.005	12.64321	100

Appendix 6: No of Plots, Altitude, AGC, Density and Richness in semi-forest coffee

Plot	Altitude	AGC (ton)	AGC t/ha	Density	D/ha	Richness
p1	1676	15.26	1.09	23	1.64	9
p2	1665	13.53	0.97	18	1.29	8
p3	1682	21.18	1.51	30	2.14	12
p4	1808	20	1.43	19	1.36	12
p5	1567	24.12	1.72	32	2.29	10
p6	1594	16.57	1.18	27	1.93	10
p7	1867	25.37	1.81	18	1.29	12
p8	1900	20.22	1.44	30	2.14	10
p9	1696	30.58	2.18	21	1.5	9
p10	1691	21.21	1.52	23	1.64	9
p11	1771	20.39	1.46	20	1.43	9
p12	1667	20.70	1.48	37	2.64	12
p13	1667	25.33	1.81	29	2.07	13
p14	1669	16.61	1.19	33	2.36	12

Appendix 7: No of Plots, Altitude, AGC, Density and Richness in pasture land

Plot	Altitude	AGC (ton)	AGC t/ha	Density	D/ha	Richness
p1	1605	9.48	0.68	8	0.6	6
p2	1588	12.61	0.90	20	1.4	10
p3	1694	1.69	0.12	5	0.4	5
p4	1690	5.43	0.39	9	0.6	6
p5	1611	10.62	0.76	17	1.2	6
p6	1550	5.44	0.39	12	0.9	7
p7	1555	5.31	0.38	24	1.7	11
p8	1577	7.00	0.50	24	1.7	8
p9	1574	5.83	0.42	18	1.3	6
p10	1533	8.48	0.61	20	1.4	10
p11	1877	5.75	0.41	10	0.7	4
p12	1923	2.33	0.17	7	0.5	5
p13	1685	5.63	0.40	11	0.8	6
p14	1672	8.62	0.62	12	0.9	7

Appendix 8: No of Plots, Altitude, AGC, Density and Richness in crop land

plots	Altitude	AGC (ton)	AGC t/ha	Density	D/ha	Richness
p1	1608	3.41	0.24	6	0.43	5
p2	1670	0.22	0.02	4	0.29	4
p3	1681	3.66	0.26	6	0.43	3
p4	1694	3.52	0.25	7	0.5	5
p5	1686	6.69	0.48	7	0.5	4
p6	1594	5.47	0.39	16	1.14	7
p7	1621	5.14	0.37	11	0.79	4
p8	1622	5.09	0.36	13	0.93	7
p9	1908	4.51	0.32	12	0.86	8
p10	1890	5.74	0.41	9	0.64	7
p11	1694	2.34	0.17	10	0.71	4
p12	1699	3.72	0.27	8	0.57	7
p13	1694	6.69	0.48	9	0.64	5
p14	1686	3.71	0.27	10	0.71	5

Appendix 9: Important value index in SFC

Semi-forest coffee				
Species name	RDM	RF	RD	IVI
Cordia africana Lam.	17.79	7.48	10.28	35.55
Millettia ferruginea (Hochst.) Bak	7.017	6.80	16.94	30.76
Croton macrostachyus A.Rich	12.98	7.48	9.17	29.63
*Sapium ellipticum (*Krauss) Pax	9.71	6.80	5	21.51
*Albizia gummifera (*J.F Gmel.) C.A. Sm.	8.99	4.76	5.56	19.31
Entada abyssinica Steud.ex A.Rich	3.44	4.76	9.72	17.93
Persea americana Mill.	5.44	4.08	7.5	17.02
Vernonia amygdalina Del.	3.80	5.44	4.72	13.97
Ehretia cymosa Thonn.	5.55	4.08	3.33	12.96
Maesa lanceolata Forssk	1.55	4.76	3.89	10.2
*Olea welwitschii (*Knobl.) Gilg. & Schellenb	4.14	4.08	1.67	9.89
Acacia abyssinica Hochst ex Benth.	1.14	2.72	1.39	5.25
Psidium guajava L.	0.91	2.72	1.39	5.02
Erythrina abyssinica Lam. Ex Dc.	2.48	0.68	1.67	4.83
Eucalyptus camaldulensis Dehnh	1.21	2.04	1.39	4.64
Ekebergia capensis Sparm.	1.07	2.04	1.11	4.22
Euphorbia abyssinica Gmel.	1.14	1.36	1.38	3.89
Bersama abyssinica Fresen	0.41	2.04	1.39	3.84
*Prunus africana (*Hook.f) Kalkm	1.69	1.36	0.56	3.60
Annona senegalensis Pers,	0.69	2.04	0.83	3.57
Ficus thonningii Blume	1.45	1.36	0.56	3.36
Syzygium guineense (Wild.) DC.	1.13	1.36	0.83	3.33
Spathodea campanulata P.Beanv	1.11	1.36	0.83	3.30
Vernonia auriculifera Hiern.	0.30	1.36	0.83	2.50
Rhus natalensis Krauss	0.37	1.36	0.56	2.29
Flacourtia indica (Brm.f.) Merr	0.35	1.36	0.56	2.27
Grevillea robusta R. Br.	0.28	1.36	0.56	2.20

Semi-forest coffee				
Species name	RDM	RF	RD	IVI
Maytenus arbutifolia (A. Rich.) Wilczek	0.16	1.36	0.56	2.08
Ficus vasta Forssk	1.03	0.68	0.28	1.99
Ficus sur Forssk	0.64	0.68	0.28	1.60
Coffea arabica L.	0.04	0.68	0.83	1.55
Euphorbia tirucalli L.	0.19	0.68	0.56	1.43
Eucalyptus globulus Labill.	0.41	0.68	0.28	1.37
Gardenia ternifolia Schumach&Thonn.	0.11	0.68	0.56	1.34
Carica papaya L.	0.28	0.68	0.28	1.24
Fagaropsis angolensis (Engl.) Dale	0.18	0.68	0.28	1.14
Celtis africana Burm.f.	0.14	0.68	0.28	1.01
Dracaena steudneri Engl.	0.11	0.68	0.28	1.07
Combretum paniculatum Vent	0.11	0.68	0.28	1.07
Pittosporum viridiflorum Sims	0.11	0.68	0.28	1.07
Grewia ferruginea Hochst. exA. Rich.	0.11	0.68	0.28	1.07
Mangifera indica L.	0.09	0.68	0.28	1.04
Clausena anisata (Wild.) Hook. F.ex.Benth	0.07	0.68	0.28	1.03
Citrus sinensis (L.) Osb.	0.06	0.68	0.28	1.02
Phoenix reclinata Jacq.	0.03	0.68	0.28	0.99

Appendix 10: Important value index in pasture land

Pasture land				
Scientific name	RDM	RF	RD	IVI
*Sapium ellipticum (*Krauss) Pax	18.03	8.60	13.48	40.11
Eucalyptus camaldulensis Dehnh	18.52	7.53	13.48	39.53
Cordia africana Lam.	14.7	8.60	6.74	30.05
Croton macrostachyus A.Rich	8.39	7.53	7.30	23.22
Acacia abyssinica Hochst ex Benth.	7.93	6.45	8.43	22.8
Entada abyssinica Steud.ex A.Rich	3.50	6.45	11.24	21.19
Syzygium guineense (Wild.) DC.	5.84	3.23	6.18	15.24
Maesa lanceolata Forssk	0.61	5.38	5.06	11.04
Flacourtia indica (Brm.f.) Merr	1.32	5.38	3.93	10.63
Ficus sur Forssk	6.45	2.15	1.69	10.29
Psidium guajava L.	0.25	3.23	2.25	5.72
Cupressus lusitanica Mill	0.88	2.15	2.25	5.28
Piliostigma thonningii (Schum.)	0.56	2.15	2.25	4.96
*Olea welwitschii (*Knobl.) Gilg. & Schellenb	1.63	2.15	1.12	4.90
Euphorbia abyssinica Gmel.	0.80	2.15	1.69	4.63
Sesbania sesban (L.) Merr.	0.16	2.15	2.25	4.56
Morus alba L.	0.32	2.15	1.69	4.16
Phoenix reclinata Jacq.	0.78	2.15	1.13	4.05
*Millettia ferruginea (*Hochst.) Bak	0.68	2.15	1.12	3.95
Bersama abyssinica Fresen	0.57	1.08	2.25	3.89
Ficus vasta Forssk	1.53	1.08	1.12	3.72
*Prunus africana (*Hook.f) Kalkm	1.69	1.08	0.56	3.32
Celtis africana Burm.f.	0.04	2.15	1.12	3.32
Ficus sycomorus L.	1.55	1.08	0.56	3.19
Combretum paniculatum Vent	0.38	1.08	1.12	2.58
Olea capensis L.	0.36	1.08	1.12	2.56
Ehretia cymosa Thonn.	0.25	1.08	1.12	2.45

Pasture land				
Scientific name	RDM	RF	RD	IVI
Erythrina abyssinica Lam.ex Dc	0.23	1.08	1.12	2.43
Rhus natalensis Krauss	0.07	1.08	1.12	2.27
Ficus thonningii Blume	0.42	1.08	0.56	2.06
Albizia gummifera (J.F. Gmel.) C.A. Sm	0.39	1.08	0.56	2.03
Terminalia schimperiana Hochst	0.29	1.08	0.56	1.93
*Polyscias fulva (*Hiern) Harms	0.28	1.08	0.56	1.91
*Diospyros abyssinica (*Hierm.) F. White	0.18	1.08	0.56	1.82
Casuarina equisetifolia L	0.11	1.08	0.56	1.75
Grevillea robusta R. Br.	0.11	1.08	0.56	1.74
Phytolacca dodecandra L.Herit.	0.07	1.08	0.56	1.71
Pittosporum viridiflorum Sims	0.06	1.08	0.56	1.70
Premna schimperi Engi.	0.05	1.08	0.56	1.69
Vernonia auriculifera Hiern.	0.05	1.08	0.56	1.68

Appendex 11: Important value index in crop land

Crop land				
Scientific name	RDM	RF	RD	IVI
Cordia fricana L Lam.	23.77	14.86	22.05	60.68
Sapium ellipticum (Krauss) Pax	16.02	8.11	9.45	33.58
Croton macrostachyus A.Rich	12.42	6.76	6.30	25.48
Eucalyptus camaldulensis Dehnh	5.81	5.41	6.30	17.51
Acacia abyssinica Hochst ex Benth.	4.96	4.05	5.51	14.53
Albizia gummifera (J.F. Gmel.) C.A. Sm	6.39	4.05	3.94	14.38
Erythrina abyssinica Lam. Ex Dc.	2.05	5.41	5.51	12.97
Phoenix reclinata Jacq.	2.77	4.05	5.51	12.33
Millettia ferruginea (Hochst.) Bak	2.69	4.05	4.72	11.47
Syzygium guineense (Wild.) DC.	2.71	2.70	3.94	9.35

Entada abyssinica Steud.ex A.Rich	2.58	4.05	2.36	8.99
Ficus sycomorus L.	3.96	2.70	1.58	8.23
Psidium guajava L.	0.82	4.05	2.36	7.23
Persea americana Mill.	0.85	2.70	3.15	6.71
Sesbania sesban (L.) Merr.	0.27	4.05	2.36	6.69
Ficus vasta Forssk	0.96	2.70	2.36	6.02
Ficus sur Forssk	3.04	1.35	0.79	5.18
Vernonia amygdalina Del.	0.81	2.70	1.58	5.09
Ricinus communis L.	0.19	2.70	1.58	4.47
Gardenia ternifolia Schumach&Thonn.	1.46	1.35	0.78	3.60
Ehretia cymosa Thonn.	1.39	1.35	0.79	3.53
Euphorbia abyssinica Gmel.	0.47	1.35	1.58	3.40
Mangifera indica L.	1.23	1.35	0.79	3.40
Eucalyptus globulus Labill.	1.05	1.35	0.79	3.19
Annona senegalensis Pers,	0.44	1.35	0.79	2.58
Cupressus lusitanica Mill	0.43	1.35	0.79	2.57
Euphorbia tirucalli L.	0.22	1.35	0.79	2.36
Citrus sinensis (L.) Osb.	0.14	1.35	0.79	2.28
Vernonia auriculifera Hiern.	0.09	1.35	0.79	2.23