Jimma University

College of Natural Sciences

Department of Biology

Woody Species Diversity and Structure of Aba Sena Natural Forest, Gimbi District, West Wollega Zone, Ethiopia

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

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Approval Sheet

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BIOGRAPHICAL SKETCH

The author was born on 11 December 1987 in Oromia Regional state, West Wollega Zone and Nedjo Woreda Leta Kemi Kebele Farmers Association. He attended elementary school (1-8) at Abdisa Aga Elementary School, secondary school (9-10) at Nedjo Secondary School and preparatory school (11-12) at Nedjo Preparatory School. Then he joined Bahir Dar University and graduated with B. Ed Degree in Biology in the year of 2011. After that, he was employed as biology teacher in Oromia regional state at Gimbi Secondary School. Then he joined School ofJimma university College of Natural Sciences Department of Biology in graduate studies, July 2015.

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LIST OF ACRONYMS

AAU: Addis Ababa University

CBD: Convention on Biological Diversity

$CO_{2:}$ Carbon dioxide

CSA: Central Statistical Agency

DBH: Diameter at Breast Height

EFAP: Ethiopian Forestry Action program

EFS: Ethiopian Forestry Society report

EPA: Environment Protection Authority

ETH: National Herbarium of Ethiopia

FAO: Food and Agriculture Organization

FRA: Forest Resources Assessment

GDP: Gross Domestic Product

IUCN: International Union for Conservation of Nature

IVI: Important Value Index

Ln: natural logarithms

MEA: Millennium Ecosystem Assessment

NGO: Non-Governmental Organization

RIL: Reduced Impact of Logging

SUA: Swedish University of Agriculture

UNEP: United Nations Environment Programme

WCMC: World Conservation Monitoring Center

ABSTRACT

The study was conducted in West Wollega, Gimbi District aimed at generating data on woody species diversity, Structure and community types of Aba Sena Natural forest. Five transect lines having a distance of 500 m from each other were laid at different altitudes. Quadrat size of 20 m ×20 m (400 m^2) were established systematically at every 25m interval along the transect lines. Data on woody species were collected from a total of 40 sampling plots. A total of 69 woody species belonging to 67 genera and 34 families were identified in Aba Sena Natural Forest categorized in plant communities. Species diversity was determined using Shannon Wiener diversity index (H`). Plant community types were determined using PC-ORD version 5.3 for windows. The overall Shannon-Wiener Diversity Index (H`) and the evenness values for the entire forest were 3.76 and 0.62 respectively. The most abundant woody species in their order of highest density were Ficus sur, Pouteria adolfi-friederici, Terminalia macaroptera, Ficus vasta, Syzygium guineense, Ochna holstii, Albizia grandibracteata respectively. The basal area of the forest is 51.68 m^2 ha^{-1}. The population structure of the forest indicated that there have been high forest degradation in the area and therefore, conservation of species, ecosystem restoration and sustainable use of the forest genetic resources are recommended as a result of this study.

Key words: Aba Sena, Plant community, Species diversity, Species richness, Vegetation structure, Woody species.

1. INTRODUCTION

1.1 Background of the study

Forests are very useful natural resources. Human beings get different uses from forest ecosystems. They aid in the maintenance of oxygen and carbon dioxide balance in the atmosphere by the process of photosynthesis. Therefore, they play important role in regulatingthe earth’s climateat local and global level. Forests are important in soil conservation by reducing surface runoff and allowing infiltration. Forests could serve for ecotourism developments, which attract tourists to increase government revenue. They are also home to a wide variety of wild animals and contribute to biodiversity conservation. However, in many regions, the ratio of natural forest is low due to anthropogenic activities (UNEP, 2001), which has made modified forests an important component in preventing the loss of biodiversity (Eycott *et al*., 2006). Planted forests, a subset of modified forests, are being expanded in area annually to combat the global trend in shrinking forest cover (FAO, 2012). When forests are destroyed, the wild animals including endemic ones lose their home and are forced to migrate. Due to forest loss, the level of carbon dioxide in the atmosphere increases leading to global warming. Destruction of woody plants also reduces the quality of land,because they anchor the soil with their roots to the ground and reduces erosion. Even though conservation of biodiversity needs effective conservation strategies of their habitat, theunderstanding of the impacts of anthropogenic disturbances on forest biodiversity is still limited (Newton and Echeverría, 2014).

Ethiopia is regarded as one of the most important countries in Africa with respect to biological resources of flora and fauna (EFAP, 1994). However, the country had experienced substantial deforestation, soil degradation and an increase in the area of bare land over the years.The number of species of higher plant taxa in Ethiopia is 5757 (excluding Eritrea) of which 9.4% are endemic to the country (Ensermu Kelbessa and Sebsebe Demissew, 2014). Ethiopia is among countries that have forest cover ranging between 10 to 30 percent of their total land area and forest cover is 12.4 milion hectares (11.5%) (FAO, 2015). The main causes of forest degradation were mainly tthe need for fuel wood, arable land and grazing thatfrequently leading to loss of forest cover and biodiversityerosion, desertification and reduced water resources (Ensermu Kelbessa and Teshome Soromessa 2008).

In the past a substantial proportion of the Ethiopian highlands were once believed to have been covered by forests having wide coverage (Friis, 1992).

The extent of Ethiopia's forests (including both forests and woodland) decreased by 1.4 million hectares between 1990 and 2000. By 2005, the forest cover had further declined and was estimated to cover 13.0 million hectares. For example, Ethiopia lost over two million hectares of forest, with an annual average loss of 140, 000 hectares between 1990 and 2005 (FAO, 2015). Moreover, in Ethiopia the contribution of forests to local livelihoods and the national economy as a whole is significant (FAO, 2015). However, it's largely unrecorded and unrecognized. Hence, thelimitations to the opportunities for income generation forced people to cultivate marginal lands and allow overgrazing and the felling of treesthat in turn exacerbated environmental degradation and deforestation (Ensermu Kelbessa *et al.*, 1992).

Nowadays there is a growing awareness of the significance of forest resources and the link between biodiversity, ecosystem services and human wellbeing (EFS, 2014) the government has launchedthe tree-planting campaign throughout the country on an annual basis since 2008 ((FAO, 2015). Forinstance the forest cover hasshownan estimated gain of 40,000 hectares annually between 2010 and 2015 (FAO, 2015).

Natural regeneration is essential for preservation and maintenance of biodiversitythat could be through natural and artificial regeneration depending on management objectives (Ref). The plant diversity of a given site can beinfluenced by species distribution and abundance patterns (Palit *et al.*, 2012) and a variety of biotic and abiotic parameters would control plant species richness of a given area by (Huston, 1994). For example, rapid human population growth, poverty, forest clearing for cultivation, over grazing, exploitation of forests for fuel wood and construction materials and lack of proper policy framework are some of the major factors that contribute to the loss of forest resources in Ethiopia (Dereje Denu, 2007).

The major causes for the forest degradation are multifaceted and attributed to mixture of different factors. The availability of accurate data on forest resources is an essential requirement for management and planning within the context of sustainable development (FAO, 2007). Moreover, assessments of woody species diversity and structure are essential in understanding the extent of plant diversity in forest ecosystem (WCMC, 1992).

Knowledge of distribution and structure of forest resources is also useful in identifying important elements of plant diversity, protecting threatened and economically important species and monitoring the state of reference among others (Segawa and Nkuutu, 2006). Several studies have been carried on assessment of woody plant species diversity and structure. Aba Sena Natural Forest is one of the forest main concern areas, which is not well managed and most of the forest area is degraded and converted to agricultural land. Therefore, the present study aimed at generating data on woody species diversity, vegetation structure and plant community of the forest.

1.2. Statement of the problem

Several studies have been conducted in Ethiopia so far did not consider Aba Sena Natural Forest, and therefore, there is limited available information on the diversity of its woody species and richness. Currently, the forest is under severe anthropogenic pressure from the local community. This calls for the need to generate relevant information in order to contribute to the conservation, management and sustainable utilization of this forest resource in particular and the biodiversity in general. There is a need to assess the woody species richness and diversity, which could contribute to the conservation and sustainable use of the forest. Therefore, the study was initiated to provide primary information on woody species diversity, population structure and plant community types of Aba Sena Natural Forest.

1.3 Research questions

1. What are the woody species richness and diversity of Aba Sena natural forest?
2. What are the vegetation structures of Aba Sena natural forest?
3. What types of plant communities are found in Aba Sena natural forest?

1.4 Objectives of the study

1.4.1 General objective

The general objective of the study was to investigate woody species diversity, vegetation structure and plant community types of Aba Sena Natural Forest.

1.4.2 Specific objectives

The specific objectives of the study were:

- To assess woody species richness and diversity of Aba Sena natural forest;
- To determine vegetation structures of Aba Sena natural forest and
- To evaluate plant community types of Aba Sena natural forest.

1.5 Scope of the Study

The study was delimited in both content and geography. The contents were delimited to investigating woody species diversity and richness. The study was also aimed to determine vegetation structure and evaluate plant communities of Aba Sena natural forest. Geographically, the study was delimited to Aba Sena natural forest.

1.6 Significance of the study

The findings of the study may help other researchers who may like to pursue further research on woody species diversity of forests. Apart from adding to knowledge, and literature on woody species diversity, the findings may be beneficial to policy makers, agricultural and forest research center, NGO and development agents since it may show the different woody plant species on their environment.Thus, the findings of the study may provide primary information about woody species diversity, population structure and plant communities of Aba Sena natural forest. The findings of the study may also help to recommend and design different strategies to reduce the impacts of local communities on forests. In addition, it may use for conservation and sustainable use of this forest.

2. REVIEW OF RELATED LITERATURE

2.1 General overview of Forests

Forests are vital to the conservation of terrestrial biodiversity, as more than a quarter of the earth's land surface is covered by forests, and more than half of the earth's terrestrial species dwell in or depend on these forests (Hassan *et al*., 2005). However, in many regions, the ratio of natural forest is low due to anthropogenic activities (UNEP, 2001), which has made modified forests an important component in preventing the loss of biodiversity (Eycott *et al*., 2006). Planted forests, a subset of modified forests, are being expanded in area annually to combat the global trend in shrinking forest cover (FAO, 2012). The role of forest plantations in supporting biodiversity is critically important in regions where natural forests have become highly modified (Irwin *et al*., 2014).

However, knowledge about plantations in biodiversity conservation is incomplete and their contribution to such conservation is still arguable (Brockerhoff et *al*., 2013). The value of forest plantations in biodiversity conservation has been found to be context dependent (Parrotta *et al*., 1997, Lamb *et al*., 2005, Carnus *et al*., 2006). Bremer and Farley (2010) used 126 observations from 36 published works to conduct a quantitative synthesis of the effects of forest plantations on plant richness in their work. They found that the effects of plantations on plant richness varied considerably depending on whether the original land cover was grassland, shrub land, primary forest, secondary forest, or degraded or exotic pasture, and whether native or exotic tree species had been planted. They suggested that plantations have positive effects on plant diversity when established on degraded lands by comparison to when they are used to replace natural ecosystems (such as forests, grasslands, and shrub lands), and when indigenous rather than exotic tree species are used (Bremer and Farley, 2010). These results provide useful information with respect to whichland types and species should be selected for afforestation in order to achieve optimal biodiversity outcomes.

2.2. Forest and climate change

Global climate change is a challenge for developing conservation strategies for forest species (Aitken *et al*., 2008), because it can modify the distribution of genes and species as well as the composition of vegetation and create new biogeoclimatic zones with individual species (Richardson *et al*., 2009).

The amount of predicted decoupling between biomes and their suitable climatic habitat vary greatly between geographic areas and depend on the level of greenhouse gas emissions in this century (Rehfeldt *et al*., 2012). Hawkins *et al*. (2003) suggested that, one of the most important patterns in ecology is the variation in broad-scale variation in taxonomic richness with climate and geography. Other studies have also demonstrated a strong relationship between total species richness and temperature, precipitation, and net primary productivity (Hawkins *et al*., 2003).

2.2.1 Plant Biodiversity Conservation

Biodiversity is a term intended to describe all of nature's variety. It refers to all aspects of variety in the living world, including the variety of species on the planet, the amount of genetic variation that exists within a species, the diversity of communities in an ecosystem and the rich variety of landscapes that occur on the planet (CBD, 2009). Species diversity has been identified as one of the key indices of sustainable land use practices and considerable resources are expended to identify and implement strategies that will reverse the current decline in biodiversity at local, regional and international scales (Shackelton, 2000).

The description of plant communities involves the analysis of plant diversity, evenness and similarity. Diversity and equitability (evenness) of species in a given plant community are used to interpret the relative variations between and within the community and helps to explain the main reason for such a difference. The idea of species diversity involves two relatively distinct concepts: species richness and evenness. Species richness refers to the total number of species in a community whereas evenness is the relative abundance of species with in the sample or community making up the richness of an area (Krebs, 1999). Diversity is, thus, measured by recording the number of species and their relative abundances. The two components may be examined separately or combined in some form of index like the Shannon diversity index. Patterns of plant species diversity have often been noted for prioritizing conservation activities because they reflect the underlying ecological processes that are important for management (Lovett *et al.* 2000).

2.2.2 Conservation Status of Biodiversity

Conservation is the management of human use of the biosphere so that it may yield the greatest sustainable benefit to current generations while maintaining its potential to meet the needs and aspirations of future generations. Thus, conservation is positive, maintenance, sustainable utilization, restoration, and enhancement of the natural environment. Biodiversity is distributed heterogeneously across the Earth, some areas are rich with biological variation (for example some moist tropical forests and coral reefs), others are virtually devoid of life (for example, some deserts and Polar Regions) and most fall somewhere in between (Gaston, 2000).

Ewnetu Dersha (2006) suggested that, Ethiopiais characterized by a wide range of edaphic and climate conditions that account for a wide diversity of its biological resources, both in terms of floral and faunal wealth and the country is recognized as one of the worlds' most important centres' of genetic diversity. Its conservation is important for sustainable development because biodiversity is the natural biological wealth that supports human life and wellbeing in agriculture, livestock, logging, and export earning, economic output and for their ecological services and functions. Vegetation types in Ethiopia are highly diverse ranging from afro-alpine to desert vegetation. It has a large number of plant species and a recent work indicated that the number of higher plants was over 7000 species from which 12 % are probably endemic (CBD, 2009).

Globally, biodiversity hotspots previously covered an area of 15.7% of the global land Surface, but currently cover only 2.3% and they are still experiencing different forms of disturbances, which constantly threaten their existences. In most cases, these disturbances are due to changes in land use, overexploitation of resources and introductions of exotic species (Myers *et al*., 2000). In 2009, the vast majority of the illegally obtained rosewood was exported to China. Since the tropical rainforests are the most diverse ecosystems on earth and about 80% of the world's known biodiversity could be found in tropical rainforests, removal or destruction of significant areas of forest cover has resulted in a degraded environment with reduced biodiversity (Sahney *et al*., 2010). A study in Rondonia, Brazil, has shown that deforestation also removes the microbial community, which is involved in the recycling of nutrients, the production of clean water and the removal of pollutants. It has been estimated that humanbeings are losing 137 plants, animal and insect species every single day due to rainforest deforestation, which equates to about 50,000 species a year.

According to Abyot Dibaba *et al.* (2014), loss of forest cover and biodiversity due to anthropogenic activities is a growing concern in many parts of the world. This is because of the fact that declining vegetation cover and depletion of natural resources are closely associated with drought and food shortages that have become major threats affecting the life of millions of people (Brook *et al*., 2006).

In addition, ineffective implementation of policies by national institutions exacerbates the losses of biodiversity in many countries, because less attention is given to ensuring that regulations that are in place for the management of these forests are implemented. This loss in biological diversity ultimately results in economic losses of the country and the world as a whole, including reduction in the quantity of carbon that can be sequestrated from the atmosphere (EFAP, 1994). Most highlands have felt the impacts of fundamental changes, as a result of the vegetation deteriorating in its biological potential from the effects of human pressure (Feyera Abdena, 2010). Although biodiversity has valuable importance and services in terms of economic, ecological and other benefits, humans have a bad record of misuse of these resources.

Generally, there are close connections between poverty, population growth, economic development, and the use of the environment (Woldeyohannes Enkossa, 2008). If present trends in population growth continue, deterioration of natural resources will be even more rapid in the future. EFAP (Ethiopian Forestry Action program, (1994) state that, this rapid depletion of the forest associated with other pressing problems such as land degradation, soil erosion, and water resource degradation also caused by an increased demand for construction inputs, over grazing, fuel wood and clearing for agricultural expansions (Alemu Abebe, 2007). The recognition of these threats to biodiversity has led to draw conservation strategies at global, national and regional levels. Again Millinnium Ecosystem Assessment (MEA, 2005), identifies that, habitat change, climate change, invasive species, over exploitation and pollution are the primary drivers leading to loss of biodiversity.

2.2.3 Values of biodiversity

Humans cannot exist without biodiversity as they use it directly and indirectly in a number of ways. Direct use includes things like food, fibres, medicines and biological control, whilst indirect uses includes ecosystem services such as atmospheric regulation, nutrient cycling and pollination (Mohammed Ahammed, 2010).

There are also non-use values of biodiversity, such as option value (for future use or nonuse), bequest value (in passing on a resource to future generations), existence value (value to people irrespective of use or non-use) and intrinsic value (inherent worth, independent of that placed upon it by humans) (Gaston and Spicer, 2004).

2.3 Vegetation types in Ethiopia

Vegetation is the total plant life or cover in an area; also used as a general term for plant life; the assemblage of plant species in a given area. Vegetation is an assemblage of plants growing together in a particular location vegetation characterization is used to indicate the identification and description of the plants in terms of location and distribution (Abebaw Zeleke 2006). Vegetation is dynamic, that is, constantly changingdue to ecological or evolutionary processes, climatic change, human land use, and interaction between factors (Birhanu Kebede, 2010). Various authors have been attempted to study the Ethiopian forests and woody vegetation resources employing different systems, among them, Tadesse WoldeMariam (2003) have made considerable contributions toward understanding the vegetation of the country and proposed their conservation strategies.

Similarly, (Kitessa Hundera *et al.*, 2007, Ensermu Kelbessa and Teshome Soromessa, 2008) provides the general description of the vegetation types and their floristic composition in different parts of Ethiopia. Based on the works of these and other authors the various vegetation types of Ethiopia have been grouped in to different categories. Natural vegetation types of of Ethiopia have been classifiedin to eight major ecosystems namely Desert and semidesert scrub land, Acacia-Commiphora woodland, Moist Montane rainforest (which includes the Afromontane rainforest and the Transitional rainforest), Lowland semievergreen forest, Combretum- Terminalia woodland and Savannah, Dry evergreen montane forest and Grassland complex.

Which can also be divided into four subtypes namely: Undifferentiated Afromontane forest, Dry single DominantAfromontane of the Ethiopia Highlands, Afromontane woodland, wooded grassland and grassland, Afro alpine and sub-afro alpine vegetation and Riparian and Swamp vegetation? From these vegetation types, the current study area, Aba Sena Natural Forest, might fit the characteristics of the Afromontane woodland forest in the country.

2.4 Vegetation Patterns along Environmental Gradients

GlobalPatterns of plant species diversity are influenced by latitudinal, altitudinal and soil gradients (Huston, 1994). Altitude is one of the most important environmental factors that determine species diversity and distribution patterns. Species diversity generally tends to decrease with increasing altitude.The interacting influences of climate, topography and soil are primary determinants of plant distribution so that variables such as vegetation structure and productivity also exhibit complex patterns along environmental gradient (Brown, 2001). Altitude affects temperature, moisture, radiation and atmospheric pressure thereby influencing the growth and development of plants and the distribution of vegetation (Getachew Tadesse *et al.*, 2005).

Plant Community Plant community type determination is a collection or association of species with designated geographical unit, which forms relatively uniform patch, distinguishable from neighboring patches of different vegetation types. Plant community types were determined by hierarchical cluster analysis using PC-ORD ecological program. Bray-Curtis was used as a distance measure and group average as a group linkage. Communities were named by species having relatively higher cover abundance values. Dominant communities were those communities defined by dominant species, which occurred uniformly throughout the sample stand (Mueller-Dombois and Ellenberg, 1974).

In general, the distribution, abundance and diversity patterns of species can result from the interaction between biotic and abiotic factors at different spatial and temporal scales (Feyera Senbeta, 2006). Variations in climate, temperature and rainfall distribution are generally reflected in the variations of the species composition and structure of communities (Grytnes and Vetaas, 2002).

2.5 Factors Affecting Woody Species Diversity

The Ethiopian biodiversity is being increasingly threatened and reduced, making Ethiopia one of the most degraded biodiversity hotspots in the world (McKee, 2007). Threats are multiple and interconnected. Human activities are driving many species to extinction and damaging or converting natural habitats around the world.

Overall, invasive alien species are posing an increasing threat to biodiversity and to the economic well-being of the population in Ethiopia, threatening agricultural land and protected areas, aggressively invading pastoral areas, destroying natural pasture, displacing native trees, forming impenetrable thickets, and reducing grazing potential.

To counter these multiple biodiversity threats, several in situ and ex situ conservation activities have been successfully launched by the Institute of Biodiversity Conservation in partnership with farming communities. The attention given to the conservation and sustainable use of all these biological diversities is inadequate due to low-level awareness of the people about the role of ecosystems (Dereje Denu, 2007).

2.5.1 Agriculture

Agriculture is the main backbone of the economy but also the major occupation of Ethiopian population. Abiot Molla and Gonfa Kewessa (2015) suggested that, rapid population growth and long history of sedentary agriculture have changed the land use/land cover systems and caused environmental degradation in many developing countries including Ethiopia. The widespread destruction of woodlands due to agriculture and other human activity throughout the savannas makes the biodiversity losses within parks even more troubling. One of the reasons for the destruction of natural forests is the expansion of agriculture.

The destruction of natural forests leads to the loss of biodiversity. The loss of biodiversity in turn has a range of ecological and societal consequences. More immediately, loss of biodiversity can have significant impacts on ecosystem function and reduces opportunities to avert production related risks (Power and Flecker, 2001). Now a day's diminution of biodiversity because of converting primary forest to unsustainable agricultural landscape has increased in many developing countries.

For instance, environmental degradation in the form of deforestation and loss of biodiversity and soil fertility is one of the most prominent features of the Ethiopian highlands. About 27 million hectares of land in highlands of Ethiopia have been significantly degraded out of which 2 million hectares are degraded to the extent that they will not produce crops in the future (EFAP, 1994).

2.5.2 Plant Community Types

Plant communities are conceived as types of vegetation recognized by their floristic composition. Distinguishing plant communities focuses on the distribution, composition and classification of plant communities. And Plant communities are separated from each other based on indicator species in combination with a distinctive floristic composition. There is no fixed size for a community. They can range from very small size to variable expanses of grassland or forest (Chapman and Reiss, 2008).

According to Kent and Coker (1992), plant community can be defined as the collection of plant species growing together in a particular location that shows a definite association with each other. Its the combination of plants that are dependent on their environment, influence one another and modify their own environment. Vegetation classification attempts to define discrete, repeatable classes of relatively homogenous vegetation communities/association about which reliable statements can be made. Classification assumes either that natural vegetation groupings do occur, or that it is reasonable to separate a continuum of vegetation composition and/or structure in to a series of arbitrary classes (Kimmins, 1997).

2.5.3 Physical environment

The growth diversity and types of woody plant species growing in a given land use are affected by altitude and climate. Temperature and rainfall are two important climatic factors that are influenced by altitude which further affect the diversity of species, under natural woodland and forest ecosystems, a large quantity of nutrients circulate annually between plants and the soil; in a climax community the plant soil system as a whole is in equilibrium and the inputs and outputs of nutrients are small (Biruk Asfaw, 2006).

2.6 Major causes of destruction of forests

2.6.1 Wood extraction

Wood extraction is the principal cause of forest degradation and can also lead to deforestation, either directly or indirectly. Wood is extracted from forests for timber, pulpwood, fuel wood and charcoal. While logging practices usually degrade forests, selective logging does not trigger severe degradation or deforestation.

A large literature on reduced impact of logging (RIL) has developed prescriptions for silvicultural and harvesting techniques, as well as pre harvest and post harvest operations. Implementation of RIL and beyond RIL recommendations can minimize the damage to the residual stand and associated biodiversity and ecosystem services, as well as reduce the chances that logging will lead to deforestation (Meijaard *et al.,* 2005).

However, uncontrolled or under-regulated timber extraction, whether legal or illegal, often leads to degradation and indirectly, to deforestation.Logging and deforestation are linked through road construction. Logging can facilitate deforestation by promoting immigration and land colonization. Road construction associated with logging frequently leads to deforestation by facilitating immigration and conversion of forests to agriculture in areas where property rights are unclear or poorly enforced (Kaimowitz *et al.*, 1998). Poor logging practices which leave behind large volumes of combustible waste make forests vulnerable to escaped fires that have been set to clear land for commercial or subsistence agriculture, further degrading the forest (Nepstad *et al.,* 1999). In Indonesia and elsewhere in Southeast Asia, illegal logging has emerged as a major force driving forest degradation (Tacconi, 2007). Other activities such as mining may also use sizeable amounts of timber or charcoal and may thereby contribute to high levels of forest degradation through direct use and population expansion.

2.6.2 Infrastructure extension

In addition, forests can also be cleared to construct roads, settlements, public services, pipelines, open-pit mines, hydro-electric dams, and other infrastructures. Indirectly, road construction and improvement is by far the infrastructure development that contributes most to deforestation (Chomitz *et al*., 2007).

This occurs not through the direct space roads occupy, but through their reduction of transport costs, which in turn, enable productive activities to take place in remote areas. Such activities often promote frontier expansion and forest destruction, as illustrated by cycles of timber harvesting, charcoal extraction and subsequent conversion to agriculture andpastures. Ecuador is one example where road building has been a prime driver of deforestation (Wunder, 2000).

Direct causes of deforestation differ significantly across countries, following broader patterns of agricultural and infrastructure expansion, and commercial and domestic demand for wood products, as illustrated by (Geist and Lambin, 2002).

2.6.3 Forest fire

Rainforests are increasingly susceptible to forest fires today due to degradation from selective logging, fragmentation, and agricultural activities. Scientists are concerned that much of the Amazon is at risk of burning, and that in the future could see fires similar to those that so damaged Indonesia in recent El Nino years. Today most rainforest fires originate in nearby pasturelands and agricultural fields where fires are used for land clearing and crop maintenance. Every year, during the burning season, land speculators, rancher's plantation owners and poor farmers to clear bush and forest set tens of thousands of fires. Under dry conditions, these agricultural forests can easily spread into neighboring rainforest. The usually strong El Nino of 1997-98 contributed to massive forest fire. The fires, started by subsequent farmers, spread rapidly across the dry savanna. As many as 3,800 square miles (10, 000 km^2) of intact rainforest were damaged or destroyed by these fires (Cochrane, 1998).

2.7 Environmental problems when forests lost

2.7.1 Climate change

Destruction of forest is a contributor to global warming and is often cited as one of the major causes of enhanced greenhouse effect. Tropical deforestation is responsible for approximately 20% of world greenhouse gas emissions. According to the Intergovernmental Panel on climate change, deforestation, mainly in tropical areas, could account for up to one-third of total anthropogeniccarbon dioxide emissions. As carbon dioxide accumulates in atmosphere, it produces a layer that traps radiation from the sun. The radiation converts to heat which causes global warming, which is better known as the greenhouse effect. Plants remove carbon in the form of carbon dioxide from the atmosphere during the process of photosynthesis, but release some carbon dioxide back into the atmosphere during normal respiration. Both the decay and burning of wood release much of this stored carbon back to the atmosphere. In order for forests to take up carbon, there must be a net accumulation of wood.

Loss of forests may also cause carbon stores held in soil to be released.Forests can be either sinks or sources of carbon dioxide depending upon environmental circumstances. Mature forests alternate between being net sinks and net sources of carbon dioxide. Burning of forest plants to clear land releases large amounts of CO_2, which contributes to global warming. Scientists also state that tropical destruction of forests releases 1.5 billion tons of carbon each year into the atmosphere (Defries, 2007).

2.7.2 Economic impact

According to British Broadcasting Corporation News, damage to forests and other aspects of nature can decrease living standards of the people and reduce global growth domestic product (GDP) by about 7% by 2050, a report concluded at the Convention on Biological Diversity (CBD) meeting in Bonn. Historically, utilization of forest products, including timber and fuel wood, has played a key role in human societies, comparable to the roles of water and cultivable land.The forest product industry is a large part of the economy in both developed and developing countries. Short-term economic gains made by conversion of forest to agricultureor over-exploitation of wood products, typically leads to loss of long-term income and long-term biological productivity. West Africa, Madagascar, Southeast Asia and many other regions have experienced lower revenue because of declining timber harvests. Illegal logging causes billions of dollars of losses to national economies annually (Keneth, 1995). The new procedures to get large amounts of wood are causing more harm to the economy and overpower the amount of money spent by people employed in logging.

Rapidly growing economies also have an effect on deforestation. Most pressure will come from the world's developing countries, which have the fastest-growing populations and most rapid economic growth. In 1995, economic growth in developing countries reached nearly 6%, compared with the 2% growth rate for developed countries. As our human population grows, new homes, communities and expansions of cities will occur. Roads, very important factors in our daily life, connect all of the new expansions. Rural roads promote economic development but also facilitate deforestation. About 90% of the deforestation has occurred within 100 km of roads in most parts of the Amazon (Ferraz, *et al.*, 2009).

2.7.3 Effect on hydrological cycle

The water cycle is also affected by destruction of forests. Trees extract groundwater by their roots and release it into the atmosphere.When part of a forest is removed, the trees no longer transpire this water, resulting in a much drier climate. Deforestation reduces the content of water in the soil and groundwater as well as atmospheric moisture. The dry soil leads to lower water intake for the trees to extract (Dandley and Stolton, 2003).Shrinking forest cover reduces the landscape's capacity to intercept, retain and transpire precipitation. Instead of trapping precipitation, which then percolates to groundwater systems, deforested areas become sources of surface water runoff, which moves much faster than subsurface flows. This quicker transport of surface water can be changed to flash flooding and more localized floods than would occur with the forest cover.

Deforestation also contributes to decreased evapotranspiration, which reduces atmospheric moisture which in some cases affects precipitation levels from the deforested area, as water is not recycled to forests, but is lost in runoff and returns directly to the oceans. In deforested north and northwest China, the average annual precipitation decreased by one third between the 1950s and the 1980s (Bruijnzeel, 2004).Trees and plants in general, affect the water cycle significantly. As a result, the presence or absence of trees can change the quantity of water on the surface, in the soil or in the atmosphere. This in turn changes erosion rates and the availability of water for either ecosystem functions or human services. Forests reduce flooding in the case of large rainfall events, which overwhelm the storage capacity of forest soil if the soils are at or close to saturation (Chomitz *et al*., 2007).

2.8 Reducing destruction of forests

2.8.1 Reforestation

In many parts of the world, especially in East Asian countries, reforestation and afforestation are increasing the area of forested lands (Foley, 2005). The amount of woodland has increased in 22 of the world's 50 most forested nations. Asia as a whole gained 1 million hectares of forest between 2000 and 2005. However, due to the large percentage of trees dying off after planting (up to 75%), the project is not very successful. There has been a 47 million hectare increase in forest area in China since the 1970s.

The total number of trees amounted to be about 35 billion and 4.55% of China's land mass increased in forest coverage. The forest coverage was 12% two decades ago and now is 16.55% (John, 2001). An ambitious proposal for China is the Aerially Delivered Reforestation and Erosion Control System and the proposed Sahara Forest Project coupled with the Seawater Greenhouse.

In Western countries, increasing consumer demand for wood products that have been produced and harvested in a sustainable manner is causing forest landowners and forest industries to become increasingly accountable for their forest management and timber harvesting practices. The Arbor Day Foundation's Rain Forest Rescue program is a charity that helps to prevent deforestation. The charity uses donated money to buy up and preserve rainforest land before the lumber companies can buy it. The Arbor Day Foundation then protects the land from deforestation. This also locks in the way of life of the primitive tribes living on the forest land.

Organizations such as Community Forestry International, Cool Earth, The Nature Conservancy, World Wide Fund for Nature, Conservation International, African Conservation Foundation and Greenpeace also focus on preserving forest habitats. Greenpeace in particular has also mapped out the forests that are still intact and published this information on the internet.World Resources Institute in turn has made a simpler thematic map showing the amount of forests present just before the age of man (8000 years ago) and the current reduced levels of forest. These maps mark the amount of afforestation required to repair the damage caused by people (Sands, 2005).

2.8.2 Tree plantations

To meet the world's demand for wood, it has been suggested by forestry writers that high-yielding forest plantations are suitable. It has been calculated that plantations yielding 10 cubic meters per hectare annually could supply all the timber required for international trade on 5% of the world's existing forestland. By contrast, natural forests produce about 1–2 cubic meters per hectare, therefore, 5–10 times more forestland would be required to meet demand (Daniel, 2001). Daniel (2001) explained that in the country of Senegal, on the western coast of Africa, a movement headed by youths has helped to plant over 6 million mangrove trees. The trees protect local villages from storm damages and provide a habitat for local wildlife. The project started in 2008, and already the Senegalese government has been asked to establish rules and regulations that would protect the new mangrove forests.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted on Aba Sena Natural Forest, Gimbi district, West Wollega Zone, Oromia Regional State, Western Ethiopia (Figure 1). Its found at about 409 km west of Finfinne/Addis Ababa and at about 32 km east of Gimbi town. Its geographical located$9^o01'$-$9^o17'$N latitude and $35^o44'$-$36^o09'$E longitude (Ghimbi District Natural Resource Management and Conservation Office, 2017). The altitude of the study area ranges from 1,300-2,222 mabove sea level. It receives mean annual rainfall of 1,000-1,800 mm and has an average temperature of 24^oC-28^oC (Ghimbi District Natural Resource Management and Conservation Office, 2017). The population of Aba Sena village was 3,243 of these 1,938 were males and 1,305 were females and the total number of households was 347 (CSA, 2007).

3.1.1 Land use, soil and topography

The physical feature of Aba Sena composed of 40.75% cultivatedland, 1.75% pastureland, and forests and woodlands cover 57.5%. Aba Sena is characterized by rugged, undulating mountains, gentle and steep slopes and leveled grounds at the bottom and at the top of the mountains (Gimbi District Rural Development Office (2017), The most dominant species of Aba Sena Natural Forest is *Pouteria adolfi-friederici*, *Combretum molle* and *Ficus sur* (Annex3). Aba Sena is characterized by loamy soil. However, the soil in this zone is vulnerable to water erosion because of the topography (Annex 7 and 8). People lead a subsistence way of life with mixed agriculture as their primary occupation. Almost all people living in the rural area are predominantly engaged in subsistence agriculture (Gimbi District Rural Development Office, 2017).

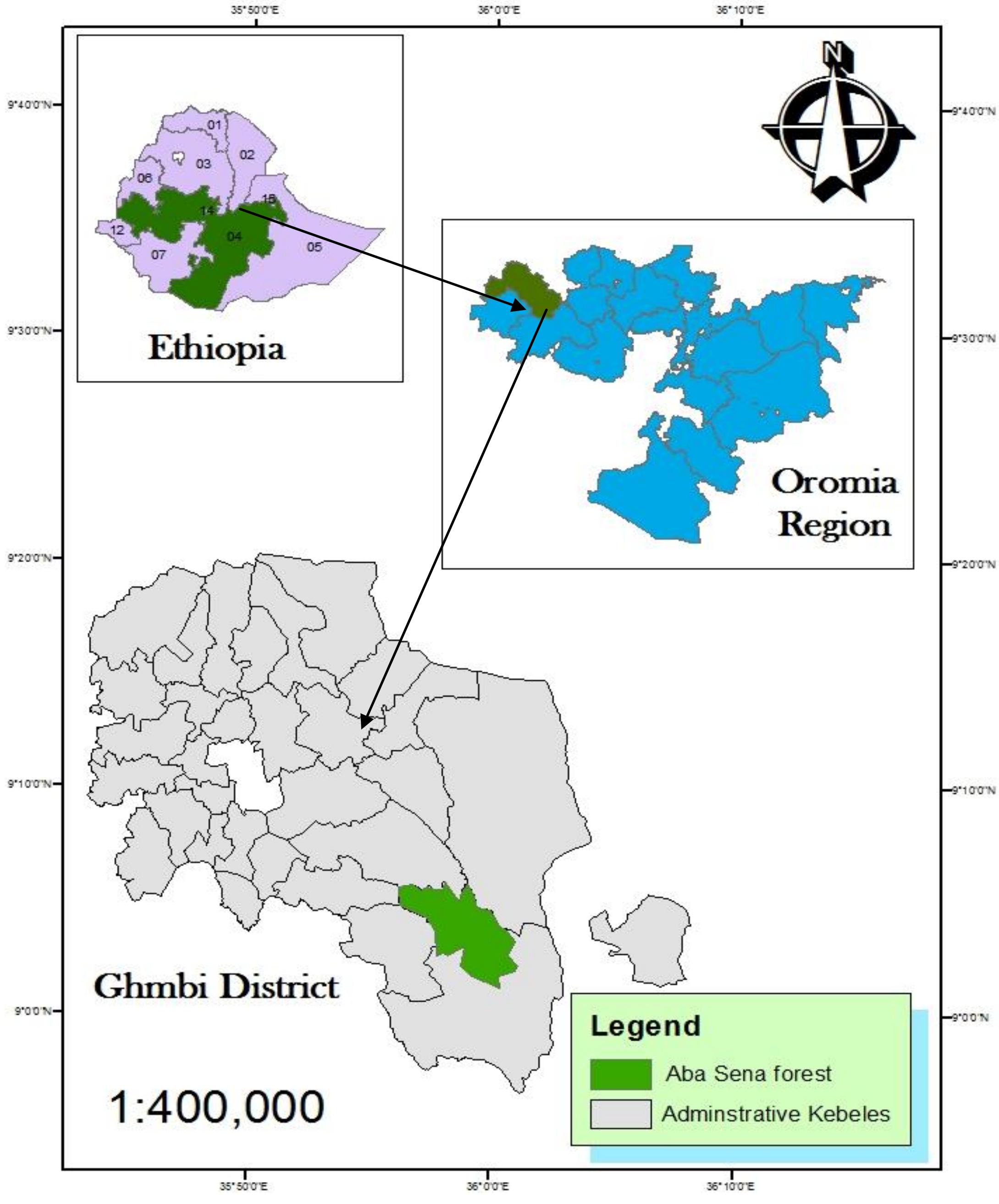

Figure 1: Map of the study area (Source: Gimbi District Natural Resources Office, 2017)

3.2. Method of Research design

3.2.1 Site selection and establishment of quadrats

A reconnaissance survey was carried out on the second week of October 2017 in order to obtain an impression of the site condition and to determine the sampling methods to be used for vegetation data collection. During that period, overall information on the study site was obtained and sampling method to be used was decided. As a result, systematic sampling method was designed to collect data. The study area was selected based on altitudinal gradients. Five transect lines were laid following the altitudinal gradients with 500 m interval between the transect lines and plots of 20 m × 20 m (n =40) were established along elevation gradients at 25 m interval. The quadrantes on the transect lines were located systematically at a distance of 25 m from each other using GPS, but the initial quadrant were selected randomly.

Data was collected from a total of 40 sampling plots of each $400m^2$ for the documentation of woody species following the Braun- Blanquet approach (Mueller-Dombois and Ellenberge, 1974; Kent and Coker, 1992). These were later used for the estimation of cover/abundance values and converted to the Braun-Blanquet 1-9 scale as follows:

1= rare generally one individual,

2= occasional < 5% cover,

3=abundant < 5% cover,

4= very abundant <5% cover,

5= cover values between 5-12%,

6= cover values between 12-25%,

7= 25-50% cover,

8= 50-75% cover and

9= 75-100% cover of the total plot area.

3.2.2 Vegetation Data collection.

Vegetation data on woody species was collected from 20 m × 20 m plots in January_ February 2018. All the woody plant species found in each sample plot were recorded and coded using the local names whenever possible. Sample specimens were collected, pressed, dried and taken to Jimma University Herbarium for identification.

Species identification was made by using published volumes (Volumes 1-8) of the Flora of Ethiopia and Eritrea (Hedberg *et al.*, 2006; Hedberg and Edwards,1995; Edwards *et al*., 2000; Gilbert, 1996; Friis, 1995; Phillips, 1995) and also by comparing them with identified specimens in the Herbarium that confirmed by expert(consulted expert). The voucher specimens were deposited in Jimma University Herbarium.Diameter at breast height of trees and shrubs was measured using a diameter tape.In each plot, trees and shrubs with Diameter at Breast Height (DBH) $\geq$2.50 cm above the ground were measured and recorded for DBH, height and cover abundance values of all woody species. The height of trees and shrubs was estimated by using clinometer. For trees and shrubs that are branched around the breast height, the circumference were measured separately and averaged. Physiographic variables such as elevation, aspect, slope and location were recorded for each sampling plot using Geographical Positioning System (GPS).

3.2.3 Method of Data Analysis

The species diversity was determined using Shannon Wiener- diversity index (H`). The index takes the species richness (the number of species in the sample plots) and evenness of species (abundance distribution among species) into consideration. Shannon-Wiener Diversity Index (H') was calculated as:

$$H' = -\sum_{n=1}^{S} \mathrm{PilnPi}$$

Where P_i= is the proportion of individuals, n = Total number of individuals, ∑= Summation symbol, S = number of species, ln= natural logarithms. Species richness was under taken from all species encountered in each plot. S = number of species/plot.

Shannon's equitability (Evenness) calculated by dividing H by Hmax (here Hmax = lnS).

E = H`/ Hmax = H`/lns

Basal Area: -It is the cross-sectional area of all stems in a stand.This basal area per unit area is used to explain the crowdedness of a stand of forests. It is expressed in square meter/hectare. Its area is also used to calculate the dominance of species.

Basal area = $(dbh/2)^2$, where dbh is diameter at breastheight.

Dominance was the product of mean basal areas of trees with the total numbers of trees per species while relative dominancy was given by the formula:

$$Relative\ dominance = \frac{Dominance\ of\ tree\ species}{Total\ dominance\ of\ the\ whole\ species} \times 100$$

The similarity in woody species composition between different community typeswas computed by using Sorensen coefficient of similarity (S_s) index:

$$Ss = \frac{2a}{2a + b + c}$$

Where a = number of species common to both communities, b = number of species in Community 1, c = number of species in Community 2.

Density: Density is defined as the number of plants of a certain species per unit area.

$$Relative\ Density = \frac{Stem\ count\ of\ a\ species}{Stem\ count\ of\ all\ species} \times 100$$

Frequency: Frequency is defined as the probability or chance of finding a plant species in a given sample area or quadrant. It is calculated as:

$$Percent\ Frequency = \frac{Number\ of\ plots\ in\ which\ a\ species\ occurs}{Total\ number\ of\ plots} \times 100$$

The frequencies of the Tree and Shrub species in all 40 quadrats were computed.

$$Relative\ Frequency = \frac{Frequency\ of\ a\ species}{Frequency\ of\ all\ species} \times 100$$

Plant community types were determined using Cluster analysis from PC-ORD ecological software version 5.3 for windows.

Importance Value Index (IVI): Is an index computed from Relative Density, Relative Dominance and Relative Frequency, which describes the structural role of a species in a stand. It is useful for making comparisons among stands in reference to species composition and stand structure (Simon Shibru and Girma Balcha, 2004). Importance Value Index (IVI) permits a comparison of the ecological significance of species in a given forest type. The IVI for each woody plant species was calculated using the formula indicated below.

IVI = Relative density + Relative frequency + Relative dominance

4. RESULTS AND DISCUSSIONS

4.1 Results

4.1.1Woody speciescomposition

A total of 69 woody species belonging to 67 genera and 34 families were recordedfrom Aba Sena Natural Forest (Annex 2). Of these species, 49 (71.01%) were trees, while 20 (28.99%) were shrubs (Annex 1). Asteraceae was the most commonfamily comprising of 7 species followed by Moraceae, Fabaceae, Rubiaceae, Combretaceae and Euphorbiaceae with 5 species each. Rutaceae, Celastraceae, Sapotaceae, Myrtaceae, Tiliaceae and Apocyanceae were composed of 2 species each. The remaining families were rarely found and represented by one species each (Annex 1). Of the woody species collected and identified from Aba Sena natural forest, *Millettia ferruginea* was the only endemic species with the least concern under the IUCN Red list category (IUCN, 2001).

4.1.2 Species Diversity

Aba Sena natural forest has shown low level of diversity with the Shannon-Wiener Diversity Index (H`) of 3.7 and uneven distribution with an evenness value of 0.62 and Equitability of 0.89.

4.1.3 Vegetation Structure

4.1.3.1 Density of Woody Species

The overall density of woody species of Aba Sena Natural Forest is 819.38ha^{-1}.Ten woody species with the highest density in decreasing order were *Pouteria adolfi-friederici (*47.50ha^{-1}), *Combretum molle (*45.00ha^{-1}), *Ficus sur (*36.88ha^{-1}), *Terminalia macaroptera (*35.63ha^{-1}), *Stereospermum kunthianum (*35.63ha^{-1}), *Dombeya quinqueseta (*35.00ha^{-1}), *Ochna holstii (*34.38ha^{-1}), *Terminalalia schimperiana (*30.63ha^{-1}), *Gardenia ternifolia (*29.38ha^{-1}) and *Millettia ferruginea (*25.00ha^{-1})(Annex 3).

4.1.3.2 Basal Area

The basal area analysis revealed that a very few woody species dominated the Aba Sena Natural forest. For instance only seven species (*Ficus sur (*14.68), *Pouteria adolfi-friederici (*6.81), *Terminalia macaroptera (*5.68), *Ficus vasta (*5.60), *Syzygium guineense (*3.38), *Ochna holstii (*3.35) and *Albizia grandibracteata* (3.11). The basal area for all woody species is indicated in (Annex 4). The total basal area of Aba Sena Natural Forest was 51.68 m^2 ha^{-1}.

4.1.3.3 Frequency

The most frequent woody species in the study area were *Combretum molle (*52.50) and *Ficus sur (*52.50) followed by *Pouteria adolfi-friederici (*50.00), *Stereospermum kunthianum (*47.50) *and Mimusops kummel (*47.50), while 11 species have shown the least occurrences in the study area (Annex 5).

4.1.3.4 Diameter and Height of Woody species

4.1.3.4.1 Diameter Class of Woody Species

The general pattern of DBH class distribution of wood species in Aba Sena Natural Forest showed an inverted J-curve distribution (Fig.2). As the DBH class size increases, the number of individuals gradually decreases ranging from 508 stems/ha in the lowest class down to 50 stems/ha in the highest DBH class. This appears to be a regular distribution that resembles the inverted J-shaped distribution of individuals in the different DBH classes (Figure 2). About 38.75% of individuals have DBH between 2.6cm and 10cm. Few individuals of *Ficus sur*, *Pouteria adolfi friederici*, *Terminalia macaroptera*, *Ficus vasta*, *Syzygium guineense*, *Ochna holstii*, *Ficus ovata*, *Albizia grandibracteata*, *Sapium ellipticum and Warburgia ugandensis* were encountered in the higher DBH classes. The middle DBH classes were also dominated by the above species.

This pattern of DBH classes indicates a good potential of reproduction and recruitment of the forest.The ratio of density of individuals with DBH > 10 cm to density of individuals with DBH > 20 cm is taken as a measure of the size class distribution (Grubb *et al*., 1963; cited in Yohannes Mulugeta *et al*., 2015).

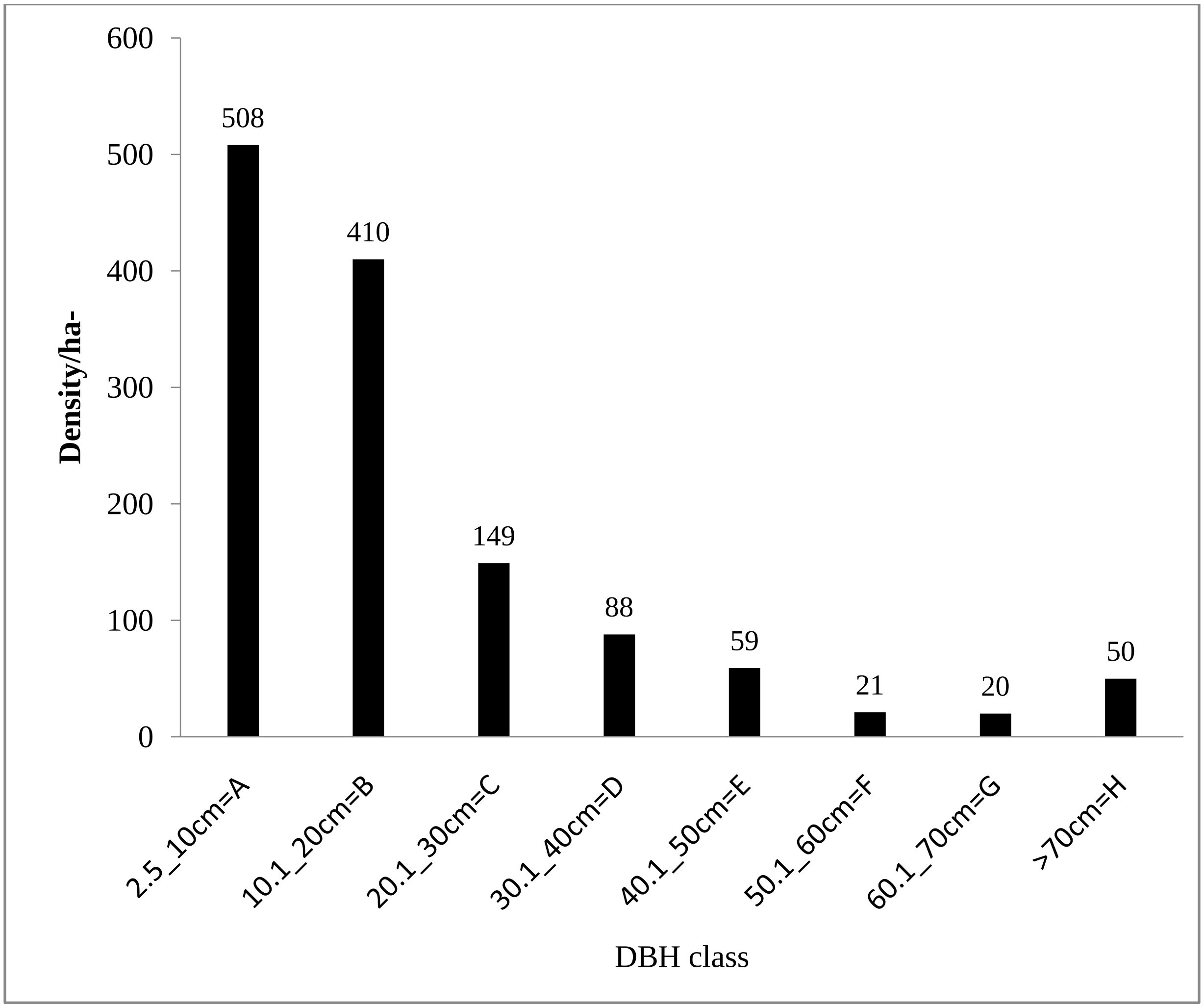

Figure 2: Density/ha of woody species in DBH classes.

Woody species density of Aba Sena Natural Forest, expressed as the number of individuals with DBH $\geq$ 2.5 cm was 819.38/ha. Individuals with DBH between 10 and 20 cm and with DBH greater than 20cm were 410/ha (31.27%) and 387/ha (29.5%), respectively (Table 4). Accordingly, the ratio of individuals between 10 and 20cm DBH to DBH > 20cm was 1.06 for Aba Sena Natural Forest, indicating a prevalence of small sized individuals.

Table 1: Distribution of individuals in different DBH classes

DBH (cm)	Density/ha	% Density
<2.5	6	0.46
2.5-10	508	38.75
10.1-20	410	31.27
>20	387	29.51

4.1.3.4.2 Height class distributions

The height class distribution of woody species in Aba Sena Natural Forest indicated that more than 876 (66.82%) of the individuals had heights less than 10 m (Figure 3). Trees representing the highest height classes, dominating the upper canopy, were *Pouteria adolfi-friederici*, *Prunus africana*, *Ficus sur*, *Albizia grandibracteata*, *Warburgia ugandensis* and *Terminalia macaroptera*. *Pouteria adolfi-friederici* is the emergent tree and grows above all the canopy trees in Aba Sena Natural Forest. Generally, the highest proportion of species is concentrated in the lower height (lower story) class followed by the middle height (middle story) and upper height (upper story) classes.

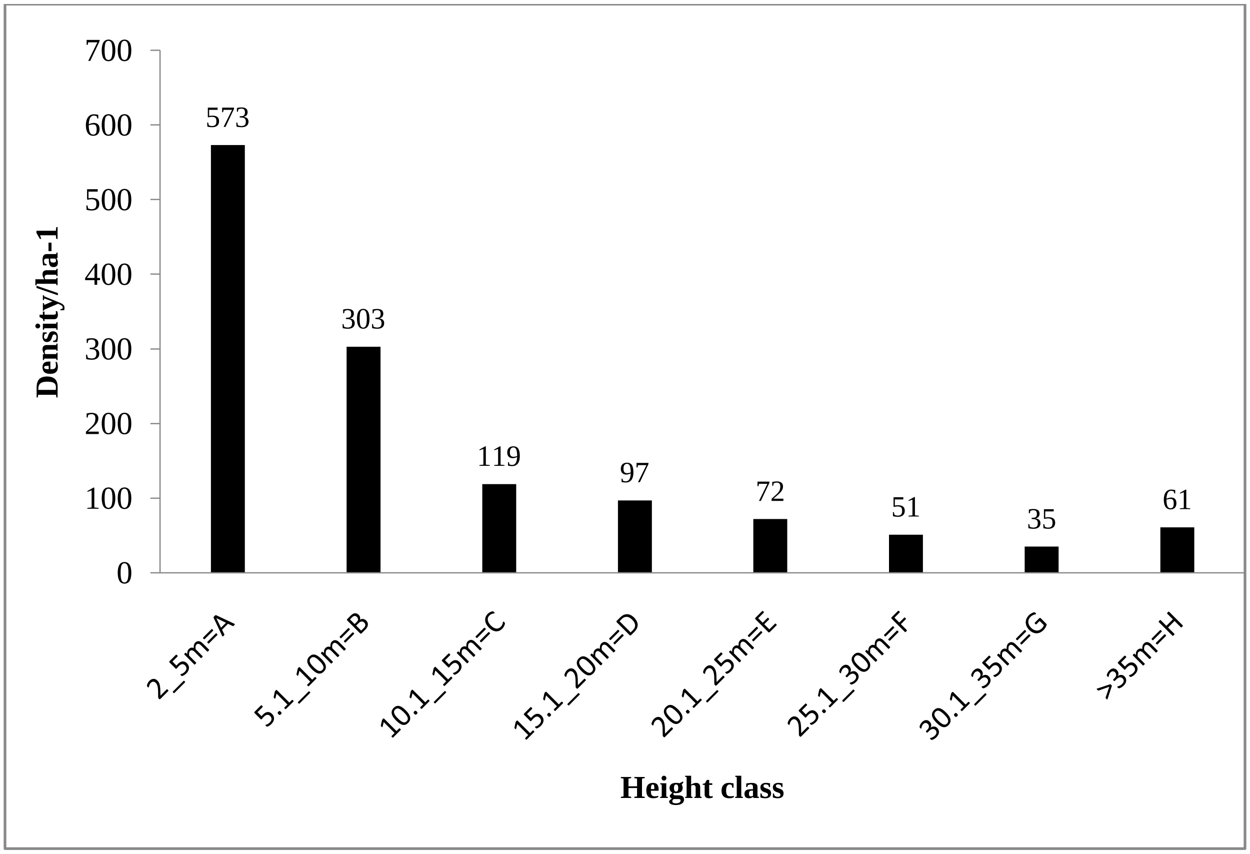

Figure 3: Distribution of individuals/ha along the height classes (Legend: A = 2-5m, B = 5.1- 10 m, C = 10.1-15 m, D = 15.1-20 m, E = 20.1-25 m, F = 25.1- 30.0 m, G = 30.1-35 m and H >35 m).

4.1.3.4.3 Important Value Index

The ten most important woody species with the highest Important Value Index **(**IVI) in decreasing order were *Ficus sur*, *Pouteria adolfi-friederici*, *Terminalia macaroptera*, *Combretum molle*, *Ochna holstii*, *Stereospermum kunthianum*, *Ficus vasta*, *Dombeya quinqueseta*, *Syzygium guineense and Terminalia schimpeneria*. However, some were with less IVI such as *Vanguaria volkensi*, *Hippocretea africana*, *Apodytes dimidiata*, *Crepis rueppellii*, *Rytigynia neglecta* (Annex 6).

4.1.4 Plant community types

Five clusters were identified from Aba Sena Natural Forest (Figure 4). Plant community types were named after two woody species with higher cover abundance value occurring in each group using the relative magnitude of the highest mean cover abundance within the cluster.

A list of the community types along with the synoptic cover-abundance values of the species is given in (Table 3).

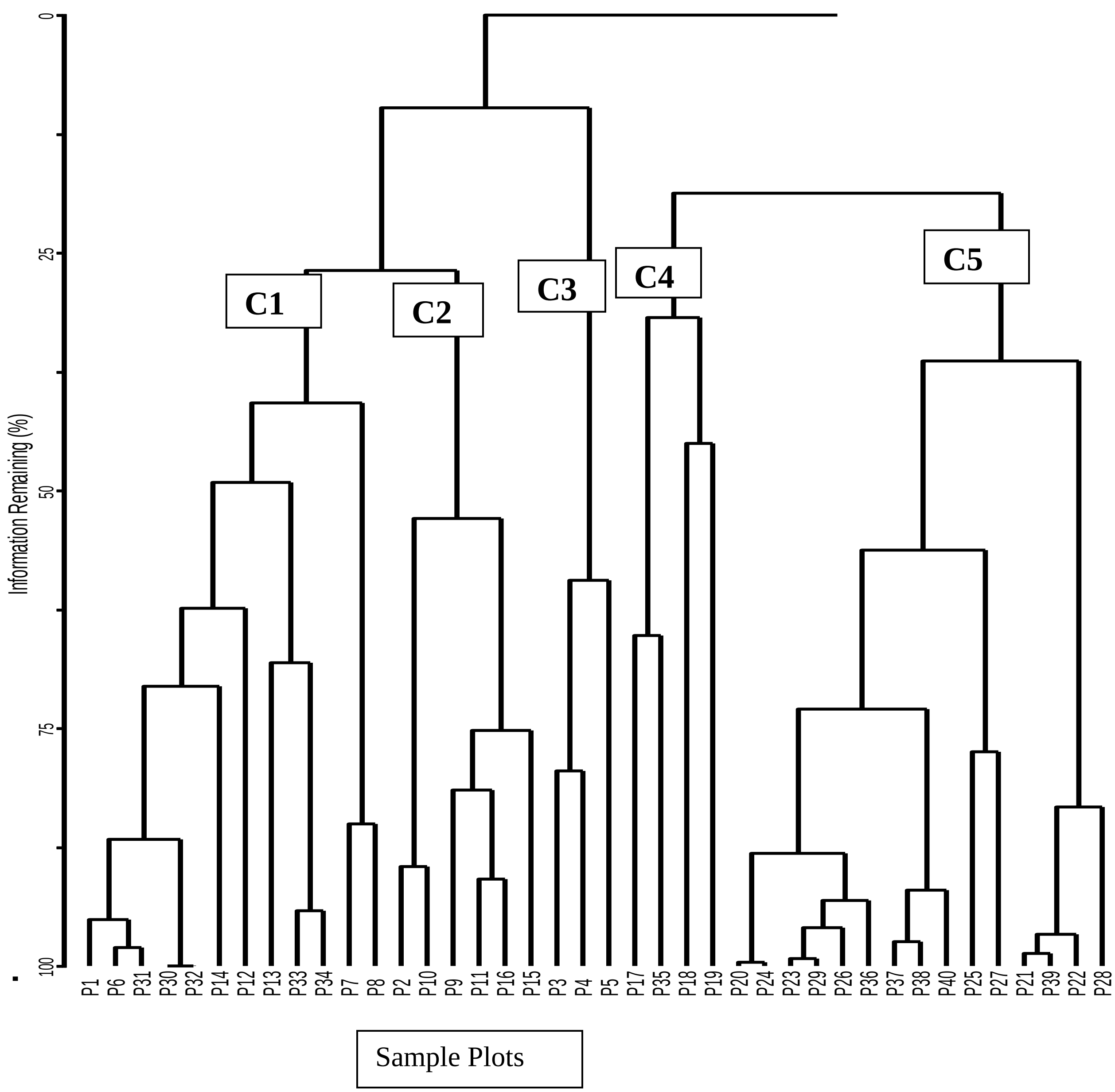

Figure 4: Dendrogram of the vegetation data obtained from hierarchical cluster analysis of AbaSena Natural Forest. *(C1 = Ficus sur - Ochna holstii Community, C2 = Pouteria adolfifriederici - Terminalia macaroptera Community, C3 = Bridelia micrantha -Celtis africana Community, C4 = Combretum molle - Syzygium guineense Community and C5 =Dombeya quinqueseta-Stereospermum kunthianum Community).*

1. *Ficus sur – Ochna holstii* community type

This community type extends from 1,461 to 1,587m a.s.l. Both are dominant species in the tree layer, *Terminalia macaroptera*, *Cordia africana*, *Mimusops kummel*, *Pouteria adolfi-friederici*, *Syzygium guineense*, *Diospyros abyssinica*, *Celtis africana*, *Millettia ferruginea*, *Albizia grandibracteata*, *Ficus vasta*, *Bridelia micrantha*, *Phoenix reclinata,* are associated tree species in this type. *Bersama abyssinica*, *Combretum collinum*, *Grewia ferruginea*, *Cassia petesiana*, *Vernonia auriculifera*, *Acalipha racemosa, Carissa spinarum* are shrub layer of this community.

2. *Pouteria adolfifriederici- Terminalia macaroptera* community type

This community type was distributed in altitudinal range of 1,459-1,596 m a.s.l. *Pouteria adolfifriederici* is the dominant species in the tree layer followed by *Ficus sur*, *Millettia ferruginea*, *Mimusops kummel*, *Warburgia ugandensis*, *Ochna holstii*, *Podocurpus falcatus*, *Cordia africana*, *Celtis africana, Albizia grandibracteata*, *Phoenix reclinata*, *Diospyros abyssinica*, *Croton macrostachyus, Ficus ovata, Stereospermum kunthianum*. *Vanguera apiculata* is the dominant species in the shrub layer of this community type followed by *Grewia ferruginea, Combretum collinum*, *Cassia petersiana*, *Lepidotrichilia volkensii,* and *Hyperecum quartinianum*.

3. *Bridelia micrantha-Celtis africana* community type

This community type was distributed at altitudes between 1,504 and 1,549 m a.s.l. *Combretum collinum* is the dominant species in the shrub layer and *Bersama abyssinica*, *Grewia ferruginea, Cassia petesiana* are shrub species community type and *Bridelia micrantha*is the dominant species in the tree layer of this type. *Celtis africana, Bridelia micrantha, Pouteria adolfifriederici, Albizia grandibracteata, Sapium ellipticum, Manilcara butuji, Croton macrostachyus, Ochna holstii, Cordia africana, Phoenix reclinata, Warburgia ugandensis,*

Stereospermum kunthianum, Flacourtia indica, Mimusops kummel, Dracaena steudneri are the associated tree species.

4. *Combretum molle - Syzygium guineense* community type

This community type extends from 1,610 to 1,685 m a.s.l. *Combretum molle* is the dominant species in the tree layer followed by *Syzygium guineense, Ficus sur, Flacourtia indica, Bridelia* *micrantha, Stereospermum kunthianum, Bauhinia toneatosa, Terminalia macaroptera, Gardenia ternifolia, Croton macrostachyus, Phoenix reclinata, Ficus ovata, Grewia bicolar, Celtis africana, Ficus vasta, Pouteria adolfi-friederici, Dombeya quinqueseta, Polyscias fulva, Sapium ellipticum, Ficus sycomorus, Cordia africana, Maytenus undata,* are the associated tree species in this community type 4, whereas *Cassia petersiana, Bersama abyssinica, Ximenia americana, Vernonia amygdalina, Lepidotrichilia volkensii, Grewia ferruginea,* are the shrub species in the layer.

5. *Dombeya quinqueseta - Stereospermum kunthianum* community type

This was distributed at the altitudes ranging from 1,471 to 1,704 m a.s.l. *Dombeya quinqueseta-Stereospermum kunthianum*are the species with the highest cover abundance value. Other trees species distributed in this community type are *Combretum molle, Maytenus undata*, *Bauhinia tomentosa*, *Gardenia ternifolia*, *Grewia bicolar*, *Ficus sycomorus*, *Polyscias fulva*, *Ficus vasta, Ficus sur* and *Celtis africana*. However, *Hyperecum quartinianum*, *Cassia petersiana*, *Ximenia americana*, are the shrub species in the lower layer.

4.1.4.1 Species diversity, richness and evenness of the plant communities

*Ficus sur - Ochna holstii*communitytype has shown highest species richness and diversity, followed by *Pouteria adolfifriederici - Terminalia macaroptera* community type exhibited species richness of 30 and Shannon diversity of 3.16 (the second highest diversity) showing the highest even distribution of species next to *Ficus sur - Ochna holstii*community type. The highest even distribution of species was observed in this community type attributed by the even distribution of the species (Table 2).

Bridelia micrantha-Celtis africana community type has the least species richness, diversity and evenness compared to all the communities except *Dombeya quinqueseta - Stereospermum kunthianum* community type in terms of species richness and diversity. *Combretum molle - Syzygium guineense* community type hashigher species richness, diversity and evenness index compared to *Bridelia micrantha - Celtis africana* community type. *Dombeya quinqueseta-Stereospermum kunthianum* community type exhibited the least species richness and diversity as well as species evenness index (Table 2). Generally, the mean evenness of the communities was more or less similar in pattern (Table 2).

Table 2: Shannon-Wiener diversity index of Community types

Community Type	Elevation range (m)	Richness	Diversity (H′)	Evenness
Community 1	1461-1587	31	3.23	0.81
Community 2	1459-1596	30	3.16	0.79
Community 3	1504-1549	23	2.92	0.80
Community 4	1610-1685	30	3.22	0.83
Community 5	1471-1704	18	2.70	0.83

4.1.4.2 Community similarity analysis

Ficus sur - Ochna holstii community type and *Pouteria adolfifriederici - Terminalia macaroptera* community type have indicated the highest similarity in species composition ratio followed by, *Pouteria adolfifriederici - Terminalia macaroptera* community type and *Bridelia micrantha - Celtis africana* community type. The least similarity was exhibited by *Ficus sur - Ochna holstii* community type and *Pouteria adolfifriederici - Terminalia macaroptera* community type with *Dombeya quinqueseta - Stereospermum kunthianum* community type (Table 3).

Table 3: Similarity coefficient among community types

Community types	Community type 1	Community type 2	Community type 3	Community type 4
Community type 2	0.87	-	-	-
Community type 3	0.77	0.79	-	-
Community type 4	0.56	0.57	0.59	-
Community type 5	0.24	0.24	0.29	0.67

4.2 Discussion

Only 69 woody species belonging to 67 genera and 34 families were identified during this study showing the low woody species richness of Aba Sena Natural Forest. The number of woody species recorded in the study was less than what was reported by Yohannes Mulugeta *et al*. (2015) for Gera forest, which was 132, by Kitessa Hundera and Tsegaye Gadissa (2008) for Belete forest, which was 79.

The woody species composition of Aba Sena natural forest is relatively higher than what was reported by Amanuel Ayanaw and Gemedo Dalle (2018) and Alemayehu Wassie (2002) for Debresena forest that was 35. Asteraceae was the species rich family in Aba Sena natural forest followed by Euphorbiaceae, Combretaceae and Moraceae. A study by Kitessa Hundera and Tsegaye Gadissa (2008) at Belete forest indicated the dominance of Fabaceae family. However, in Aba Sena Natural forest, Asteraceae family was dominant followed by Fabaceae and Moraceae.

Generally, only few species were dominating the vegetation of the study area in their abundance while many of the species were very rare or low in their abundance. Commonly, factors like human and environmental influences have a strong impact on forest structure and species richness. Possible reasons for these differences may be laid on forest size and landscape fragmentation. Study carried out in the coffee forest areas of south-west Ethiopia reveals that deforestation is increasing because of human activities (Dereje Tadesse, 2007). Another similar study carried out in southern Ethiopia on spatio-temporal forest cover change also identifies that the rate of deforestation is increasing (Workaferahu Amenashewa, 2015). However, the degree of the problem varied among the species. Diversity Index of Aba Sena Natural Forest was 3.76 which is higher than that of Harenna forest (2.60) (Feyera Senbeta, 2006).

The general pattern of DBH class distribution of the forest showed an inverted J-curve distribution(Figure 2). This pattern of DBH classes indicates a good potential of reproduction and recruitment of the forest. Feyera Abdena (2010) reported similar results, high species diversity and evenness could be attributed to the presence of optimum environmental factors such as altitude, slope and topography of the forest.

Reports from other studies indicated that species richness and diversity tend to peak at an intermediate altitude and decline at the lower and upper elevations (Alemayehu Wassie, 2002). The result of the present study more or less agrees with this findings regarding species richness. Above 83.68% of the total density restricted in the middle and higher diameter class (5-70cm), whereas, about 15.87% of density was found to be in the lower diameter classes (1-4cm). This indicated that there was drawing out of trees for various purposes by local inhabitant example for fencing and fuel wood, or trampled or browsed by livestock.

In case of height class distribution, the highest density was found in the lower height class implying that the forest has been heavily influenced by the local anthropogenic activities through selective cutting for fuel wood, construction and illegal wood harvest for timber production as it is now in different stages of secondary development. Currently, there are some large trees and small to medium-sized individuals. The dominance of small-sized individuals is the attribute of good regeneration but low recruitment, which might have been caused by anthropogenic activities.

Density is affected by quadrant size and pattern of species growth. Species-abundance measures are ways of expressing not only the relative richness but also evenness and there by assessing diversity. According to Getachew Tesfaye and Abiyot Berhanu (2002), higher number of large-sized individuals in the upper height class in the natural forest implies the presence of a good number of adult tree species for reproduction. This argument holds not true for Aba SenaNatural Forest. This is partly due to the presence of large-scale timber use.As aresult, most trees that are used for timber production such as *Cordia africana*, *Prunus africana*, *and Podocurpus falcatus* were less in number in the study area.

Therefore, the current study showed a condition of primary forest development of Aba Sena Natural Forest. Noteworthy is that woody species with the highest DBH size were also recorded for the highest height. Although there is selective logging of tree species at certain height, Aba Sena Natural Forest exhibited individuals of all height classes.

Table 4: Comparisons of tree densities with DBH between 10 and 20cm (a) and tree densities with DBH > 20cm (b) of Aba Sena Natural Forest with 8 other forests in Ethiopia

Forests	a	b	(a/b)	Sources
Gera	516	304	1.69	Yohannes Mulugeta *et al*. (2015)
Alata-Bolale	365	219	1.67	Woldeyohannes Enkossa (2008)
Bibita (Gura Ferda)	500	263	1.90	Dereje Denu (2007)
Dodola	521	351	1.48	Kitessa Hundera *et al.* (2007)
Donkoro	526	285	1.90	Abate Ayalew *et al.* (2006)
Jibat	565	287	1.96	Tamrat Bekele (1993)
Menna-Angetu	292	139	2.10	Ermias Lulekal *et al.* (2008)
Sese	513.7	412.7	1.24	Shiferaw Belachew (2010)
Aba Sena	410	387	1.06	Present study

In this study, basal area analysis across individual species revealed that there was high domination by very few or small woody species. The basal area of the forest is 51.68 m^2 per hectare, which is lower than some forests like Bibita (Gura Ferda) natural forest which was 69.9m^2 (Dereje Denu, 2007), Masha Anderacha which was 81.9 (Kumelachew Yeshitela and Taye Bekele (2003). However, higher than some forests like Jibbat forest which was 47.5 m^2 (Tamrat Bekele, 1993), Donkoro forest which was 45 m^2 (Abate Ayalew *et al.*, 2006). This is due to the nature of the plants not to grow to higher Basal Area. This also indicates that species with the highest basal area do not necessarily have the highest density, indicating size difference between species (Tamrat Bekele, 1993).

Frequency reflects the pattern of distribution and gives an approximate indication of the heterogeneity of a stand (Lamprecht, 1989). The most frequent species in this study was *Ficus sur* and *Combretum molle* occurring in 21 plots. In addition, *Ficus sur* has highest IVI than all the rest.

The species might have a wide range of seed dispersal mechanisms using wild animals, livestock, birds and the like. High values in lower frequency classes and low values in higher frequency classes on the other hand indicate a high degree of floristic heterogeneity (Simon Shibruand Girma Balcha, 2004). In the present study, high values were obtained for lower frequency classes, whereas, higher frequency classes had lower values. Thus, Aba Sena Natural Forest is floristically heterogeneous (Annex 5 and 6).

Importance value index indicates the structural importance of a species within a stand of mixed species and its calculated by summing up the relative percentages of basal area, density and frequency of species in the study area. As indicated by Lamprecht (1989), it is used for comparison of ecological significance of species in which high IVI value indicates that the species sociological structure in the community is high. It was also stated that, species with the greatest importance value are the leading dominant of specified vegetation (Simon Shibru and Girma Balcha, 2004). Thus, IVI is the most reasonable aspect in the vegetation study. Moreover, species with the highest importance value index are the most dominant of particular vegetation. It indicates that those woody species with the highest IVI are ecologically the most important ones in the study area (Annex 6).

Species with high contribution to the total IVI in this study were *Ficus sur, Pouteria adolfi-friederici, Terminalia macaroptera, Combretum molle, Ochna holstii, Stereospermum kunthianum*,*Ficus vasta, Dombeya quinqueseta* and *Syzygium guineense* whereas, species with the least contribution to the total IVI were *Hyperecum quartinianum, Crepis rueppellii, Grewia mollis, Echinops macrochactus*, *Vanguaria volkensi*, *Allophylus abyssinicus*, *Manilcara butuji* and *Rytigynia neglecta.*

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study provides useful information on the present condition of the woody species diversity, vegetation structure and plant communities of Aba Sena Natural Forest. The study showed that only few species had high density and basal area scores. The most important tree species in this study was *Ficus sur* followed by *Pouteria adolfi-friederici, Terminalia macaroptera*, and *Combretum molle;* however, relative to their basal area and frequency, their regeneration status is under question. Economically important indigenous species such as *Cordia africana*, *Prunus africana, and Podocurpus falcatus* were poorly represented.

Both the cumulative diameter and height class frequency distribution patterns of woody species have an irregular shape pattern. The variation in species composition and diversity among communities could be associated with different factors, such as altitude, anthropogenic impacts and topography of the forest.

In addition, the inhabitants of the area explained that the current human activities that lead to destruction of forest are becoming more severe than in the past. The forest cover of the area is also decreasing rapidly. Thus, it shows that deforestation is increasing in the area.

5.2 Recommendations

Aba Sena Natural Forest is currently being exploited by the local people. This calls for the need of serious attention for conservation and management of this forest as a whole. Hence, the following points are drawn as recommendations.

- Biodiversity conservation institution and other governmental and non-governmental organizations have to give due attention to the loss of plants in the area and device ways of protecting Aba Sena Natural forest.
- The government and other stakeholders in the area have to intervene in to the activities of the local community and device ways of reducing destruction of forest.
- Ghimbi Woreda Natural Resource Management and Conservation Office also have to carry out its responsibility to protect plant species from destruction by the local people.

- The people have to be supported to search for sustainable alternative source of income rather than depending on immediate sources that increase the chances of deforestation.
- Raising awareness of local communities on the value of forest resources and ecological consequences of destruction of forest should be done.
- The local communities have to get awareness that illegal timber and charcoal production has great negative impact on vegetation.
- The local communities have to use a way that enables them to obtain high yield from small number of domestic animals so that overgrazing is reduced.
- The use of alternative sources of energy such as biogas production has to be practiced in different areas to reduce charcoal production and selling.
- Tree planting by the local community has to be encouraged to reduce the pressure on the natural forests.
- The present study was limited to diversity, vegetation structure of woody species and plant communities, further studies on regeneration status; carbon storage, soil seed bank, seed physiology; herbaceous plants and land use management system in the area are recommended.

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APPENDICES

Annex 1: List of woody species and families collected during the study

(T= Trees, S= Shrubs, *= No local name)

No	Species	Local name	Family	Habit
1	*Acalipha racemosa*	Qacamaa	*Euphorbiaceae*	S
2	*Albizia adianthifolia(*Schumach)	*	*Fabaceae*	S
3	*Albizia grandibracteata*	Yangoo	*Fabaceae*	T
4	*Allophylus abyssinicus*	Marqaqqoo	*Sapindaceae*	T
5	*Apodytesdimidiata*	Wandabi'oo	*Icacinaceae*	T
6	*Bauhinia tomentosa*	Liilluu	*Fabaceae*	T
7	*Bersama abyssinica* Fresen	Lolchiisaa	*Melianthaceae*	S
8	*Bridelia micrantha* (Hochst.)Baill	Galaanoo	*Euphorbiaceae*	T
9	*Carissa spinarum* L.	Hagamsa	*Apocynaceae*	S
10	*Cassia petersiana* Bolle	Raamsoo	*Fabaceae*	S
11	*Celtis africana* Burm.f.	Ce'yii	*Ulmaceae*	T
12	*Chionahshus mildbraedii*	*	*Oleaceae*	T
13	*Clausena anisata* (Wild.)Benth	Uluma'ii	*Rutaceae*	T
14	*Combretum collinum*	Haddajaboo	*Combretaceae*	S
15	*Combretum collinum* Fresen	Ununuu	*Combretaceae*	T
16	*Combretum molle*	Dhandhassa	*Combretaceae*	T
17	*Cordia africana* Lam.	Waddeessa	*Boraginaceae*	T

18	*Crepis rueppellii* Sch.Bip*	Aannanee	*Asteraceae*	S
19	*Croton macrostachyus* Del.	Bakkanniisa	*Euphorbiaceae*	T
20	*Diospyros abyssinica*	Koshkoshii	*Ebenaceae*	T
21	*Dombeya quinqueseta (*Del.) Exell	Adaannisa	*Sterculiaceae*	T
22	*Dracaena steudneri* Engler	Afarfattuu	*Dracaenaceae*	T
23	*Echinops macrochactus* Fresen	Qabarichoo	*Asteraceae*	S
24	*Ficus exasperata* Vahl	Baalan-soofii	*Moraceae*	T
25	*Ficus ovata* Vahl	Qilinxoo	*Moraceae*	T
26	*Ficus sur* Forssk	Arbuu	*Moraceae*	T
27	*Ficus sycomorus* L.	Odaa	*Moraceae*	T
28	*Ficus vasta* Forssk	Qilxuu	*Moraceae*	T
29	*Flacourtia indica* (Burm.t.)Merr	Akukkuu	*Flacourtiaceae*	T
30	*Gardenia ternifolia*Schumach &Thonn	Gambeela	*Rubiaceae*	T
31	*Grewia bicolar*Juss	Harooressa	*Tiliaceae*	T
32	*Grewia ferruginea* Hochst.EXA.Rich	Dhoqonuu	*Tiliaceae*	S
33	*Grewia mollis*	*	*Malvaceae*	T
34	*Grewiamicrocos* L.	*	*Tiliaceae*	T
35	*Hippocretea africana*	Hidda Geeboo	*Apocyanceae*	S
36	*Hyperecum quartinianum*	Uleefoonii	*Euphorbiaceae*	S
37	*Lepidotrichilia volkensii (*Gurke) Leroy	Dhama'ee	*Meliaceae*	S
38	*Manilcara butuji*	Buttujjii	*Sapotaceae*	T
39	*Maytenus gracilipes*	Kombolcha	*Celastraceae*	T

40	*Maytenus undata (*Thunb.)Blaketlock	Ililkee	*Celasteraceae*	T
41	*Millettia ferruginea* (Hochst.)Baker	Sootalloo	*Fabaceae*	T
42	*Mimusops kummel* A.DC	Qolaatii	*Sapotaceae*	T
43	*Ochna holstii* Engl	Qunee	*Ochnaceae*	T
44	*Phoenix reclinata* Jacq.	Meexxii	*Arecaceae*	T
45	*Podocurpus falcatus (*Thumb.) Mirb	Birbisa	*Podocarpaceae*	T
46	*Polyscias fulva (*Heirn.)Harms	Bolxoqqoo	*Araliaceae*	T
47	*Pouteria adolfi-friederici (*Engl.) Baehni	Qaraaroo	*Sapotaceae*	T
48	*Protea gaguedi* .J.F. Gamel	Yuubdoo	*Proteaceae*	T
49	*Prunus africana* (Hook.f.)Kalkam	Hoomii	*Rocaceae*	T
50	*Rhus ruspolii*Engl.	Xaxessaa	*Anacardiaceae*	T
51	*Rytigynia neglecta (*Hiern.)Robyns	Mixoo	*Rubiaceae*	S
52	*Sapium ellipticum (*Krauss)Pax	Bosoqa	*Euphorbiaceae*	T
53	*Securidaca longepedunculata* Fresen	Xabanayii	*Polygalaceae*	T
54	*Stereospermum kunthianum*cham.	Botoroo	*Bignoniaceae*	T
55	*Syzygium guineense (*Wild.)DC	Baddeessaa	*Myrtaceae*	T
56	*Syzygium guineense subsp.guineensis* (Willd.) DC.	Goosuu	*Myrtaceae*	T
57	*Terminaliaschimperiana*	Dabaqqaa	*Combretaceae*	T
58	*Terminalia macaroptera* Guill &Perr	Diimoo	*Combretaceae*	T
59	*Terminalia*sp.	Gaarrii	*Combretaceae*	T
60	*Vanguaria volkensi*	*	*Rubiaceae*	T
61	*Vanguera apiculata*	Buruurii	*Rubiaceae*	S

62	*Vepris dainelli(*Pich.serrn)Kokwaro	Hadhesa baala bal'aa	*Rutaceae*	T
63	*Vernonia adoensis* Sch.bip.exWalp	Sooyyama	*Asteraceae*	S
64	*Vernonia amygdalina* Del.	Eebicha	*Asteraceae*	S
65	*Vernonia auriculifera*Hiern	Reejjii	*Asteraceae*	S
66	*Vernonia hymenolepis*	Tittibboo	*Asteraceae*	S
67	*Vernonia wollastonii* S.moora	*	*Asteraceae*	T
68	*Warburgia ugandensis* Sprague	Biiftii	*Canellaceae*	T
69	*Ximenia americana* L.	Hudhaa	*Olacaceae*	S

Annex 2: Plant families with their genera and species distribution in Aba Sena Natural forest

Family name	Number of genera	Number of species
Anacardiaceae	1	1
Apocyanceae	2	2
Araliaceae	1	1
Arecaceae	1	1
Asteraceae	7	8
Bignoniaceae	1	1
Boraginaceae	1	1
Canellaceae	1	1
Celastraceae	2	2
Combretaceae	5	5
Dracaenaceae	1	1
Ebenaceae	1	1
Euphorbiaceae	5	5
Fabaceae	5	5

Flacourtiaceae	1	1
Icacinaceae	1	1
Malvaceae	1	1
Meliaceae	1	1
Melianthaceae	1	1
Moraceae	5	6
Myrtaceae	2	2
Ochnaceae	1	1
Oleaceae	1	1
Podocarpaceae	1	1
Polygalaceae	1	1
Proteaceae	1	1
Rocaceae	1	1
Rubiaceae	4	4
Rutaceae	2	2
Sapindaceae	1	1
Sapotaceae	3	3
Sterculiaceae	1	1
Tiliaceae	2	3
Ulmaceae	1	1
34	67	69

Annex 3: Density and relative density (RD) of woody species

Species	Density	Relative Density
Pouteria adolfi-friederici	47.50	5.80
Combretum molle	45.00	5.49
Ficus sur	36.88	4.50
Terminalia macaroptera	35.63	4.35
Stereospermum kunthianum	35.63	4.35
Dombeya quinqueseta	35.00	4.27
Ochna holstii	34.38	4.20
Terminalalia schimperiana	30.63	3.74
Gardenia ternifolia	29.38	3.59
Millettia ferruginea	25.00	3.05
Mimusops kummel	25.00	3.05
Bersama abyssinica	23.13	2.82
Celtis africana	22.50	2.75
Syzygium guineense	22.50	2.75
Grewia bicolar	21.88	2.67
Maytenus undata	20.00	2.44
Bridelia micrantha	18.13	2.21
Bauhinia toneatosa	18.13	2.21
Cordia africana	16.88	2.06
Albizia adianthifolia	16.25	1.98
Diospyros abyssinica	15.00	1.83
Cassia petesiana	14.38	1.75
Albizia grandibracteata	13.75	1.68
Combretum collinum	13.13	1.60
Phoenix reclinata	12.50	1.53
Croton macrostachyus	11.88	1.45
Flacourtia indica	11.88	1.45
Securidaca longepedunculata	11.25	1.37
Polyscias fulva	10.00	1.22
Protea gaguedi	9.38	1.14
Warburgia ugandensis	8.75	1.07
Podocurpus falcatus	8.75	1.07
Sapium ellipticum	8.13	0.99
Ficus vasta	8.13	0.99
Dracaena steudneri	7.50	0.92
Terminalia sp.	7.50	0.92
Combretum collinum	6.88	0.84

Vepris dainelli	6.25	0.76
Vanguera apiculata	6.25	0.76
Grewia ferruginea	6.25	0.76
Ficus ovate	6.25	0.76
Ficus sycomorus	6.25	0.76
Manilcara butuji	5.00	0.61
Ximenia americana	4.38	0.53
Acalipha racemosa	4.38	0.53
Vernonia amygdalina	3.75	0.46
Lepidotrichilia volkensii	3.13	0.38
Chionahshus mildbraedi	3.13	0.38
Carissa spinarum	3.13	0.38
Rhus ruspolii	2.50	0.31
Clausena anisata	1.88	0.23
Vernonia auriculifera	1.88	0.23
Prunus africana	1.88	0.23
Vernonia adoensis	1.88	0.23
Syzygium guineense subsp.guineensis	1.88	0.23
Ficus exasperata	1.88	0.23
Maytenus gracilipes	1.25	0.15
Vernonia hymenolepis	1.25	0.15
Rytigynia neglecta	0.63	0.08
Crepis rueppellii	0.63	0.08
Apodytes dimidicata	0.63	0.08
Hippocretea africana	0.63	0.08
Allophylus abyssinicus	0.63	0.08
Grewiamicrocos	0.63	0.08
Echinops macrochactus	0.63	0.08
Vanguaria volkensi	0.63	0.08
Grewia mollis	*0.63*	*0.08*
Hyperecum quartinianum	*0.63*	*0.08*
Vernonia wollastonii	*0.63*	*0.08*

Annex 4: Basal area (BA) in m^2, dominance and Relative dominance of woody species

Species	Basal Area	BA/ha-1	Dominance	Relative Dominance	Rank
Ficus sur	14.68	9.17	5.73	17.75	1
Pouteria adolfi-friederici	6.81	4.25	2.66	8.23	2
Terminalia macaroptera	5.68	3.55	2.22	6.86	3
Ficus vasta	5.60	3.50	2.19	6.77	4
Syzygium guineense	3.38	2.11	1.32	4.09	5
Ochna holstii	3.35	2.09	1.31	4.05	6
Ficus ovate	3.21	2.01	1.25	3.88	7
Albizia grandibracteata	3.11	1.94	1.22	3.76	8
Sapium ellipticum	2.86	1.79	1.12	3.46	9
Warburgia ugandensis	2.73	1.71	1.07	3.31	10
Combretum molle	2.61	1.63	1.02	3.16	11
Bridelia micrantha	2.53	1.58	0.99	3.06	12
Podocurpus falcatus	2.13	1.33	0.83	2.58	13
Aibizia adianthifolia	2.02	1.26	0.79	2.45	14
Dombeya quinqueseta	2.01	1.26	0.79	2.43	15
Grewia bicolar	1.96	1.23	0.77	2.38	16
Combretum molle	1.78	1.11	0.70	2.16	17
Celtis africana	1.77	1.10	0.69	2.14	18
Stereospermum kunthianum	1.76	1.10	0.69	2.13	19
Mimusops kummel	1.61	1.01	0.63	1.95	20
Ficus sycomorus	1.46	0.91	0.57	1.77	21
Cordia africana	1.44	0.90	0.56	1.74	22
Croton macrostachyus	1.14	0.71	0.44	1.37	23
Millettia ferruginea	0.93	0.58	0.36	1.12	24
Bersama abyssinica	0.79	0.50	0.31	0.96	25
Bauhinia tometosa	0.70	0.44	0.28	0.85	26
Ficus exasperata	0.67	0.42	0.26	0.81	27
Maytenus undata	0.62	0.39	0.24	0.75	28
Gardenia ternifolia	0.45	0.28	0.18	0.55	29
Protea gaguedi	0.39	0.25	0.15	0.47	30
Securidaca longepedunculata	0.35	0.22	0.13	0.42	31
Diospyros abyssinica	0.33	0.21	0.13	0.40	32
Polyscias fulva	0.29	0.18	0.11	0.35	33
Terminalia sp.	0.25	0.16	0.10	0.31	34
Combretum collinum	0.20	0.13	0.08	0.24	35
Syzygiumguineense subsp.guineensis	0.18	0.11	0.07	0.22	36
Flacourtia indica	0.12	0.07	0.05	0.14	37
Phoenix reclinata	0.11	0.07	0.04	0.14	38

Cassia petesiana	0.11	0.07	0.04	0.14	39
Rhus ruspolii	0.08	0.05	0.03	0.10	40
Dracaena steudneri	0.07	0.05	0.03	0.09	41
Chionahshus mildbraedi	0.06	0.04	0.02	0.07	42
Combretum collinum	0.05	0.03	0.02	0.07	43
Prunus africana	0.05	0.03	0.02	0.06	44
Vernonia amygdalina	0.04	0.03	0.02	0.05	45
Grewia ferruginea	0.03	0.02	0.01	0.04	46
Lepidotrichilia volkensii	0.02	0.01	0.01	0.03	47
Acalipha racemosa	0.02	0.01	0.01	0.03	48
Vanguera apiculata	0.02	0.01	0.01	0.02	49
Vepris dainelli	0.01	0.01	0.01	0.02	50
Ximenia americana	0.01	0.01	0.00	0.01	51
Carissa spinarum	0.01	0.01	0.00	0.01	52
Apodytes dimidicata	0.01	0.00	0.00	0.01	53
Clausena anisata	0.01	0.00	0.00	0.01	54
Vernonia auriculifera	0.01	0.00	0.00	0.01	55
Vernonia hymenolepis	0.00	0.00	0.00	0.00	56
Vernonia adoensis	0.00	0.00	0.00	0.00	57
Vernonia wollastonii	0.00	0.00	0.00	0.00	58
Maytenus gracilipes	0.00	0.00	0.00	0.00	59
Crepis rueppellii	0.00	0.00	0.00	0.00	60
Hyperecum quartinianum	0.00	0.00	0.00	0.00	60
Grewiamicrocos	0.00	0.00	0.00	0.00	62
Grewia mollis	0.00	0.00	0.00	0.00	62
Echinops macrochactus	0.00	0.00	0.00	0.00	64
Vanguaria volkensi	0.00	0.00	0.00	0.00	64
Allophylus abyssinicus	0.00	0.00	0.00	0.00	66
Rytigynia neglecta	0.00	0.00	0.00	0.00	68
Manilcara butuji	0.00	0.00	0.00	0.00	69
		51.68	**32.30**	**99.99**	

Annex5: Frequency, percentage Frequency and Relative Frequency distribution of woody species of Aba Sena Natural Forest

Species	Frequency	% Frequency	Relative Frequency
Combretum molle	21	52.50	3.57
Ficus sur	21	52.50	3.57
Pouteria adolfi-friederici	20	50.00	3.40
Stereospermum kunthianum	19	47.50	3.23
Mimusops kummel	19	47.50	3.23
Terminalia macaroptera	18	45.00	3.06
Ochna holstii	18	45.00	3.06
Terminalia schimperiana	18	45.00	3.06
Celtis africana	18	45.00	3.06
Cordia africana	18	45.00	3.06
Gardenia ternifolia	17	42.50	2.89
Dombeya quinqueseta	16	40.00	2.72
Bersama abyssinica	16	40.00	2.72
Phoenix reclinata	16	40.00	2.72
Syzygium guineense	15	37.50	2.55
Grewia bicolar	15	37.50	2.55
Millettia ferruginea	14	35.00	2.38
Maytenus undata	14	35.00	2.38
Bauhinia toneatosa	14	35.00	2.38
Bridelia micrantha	14	35.00	2.38
Albizia adianthifolia	14	35.00	2.38
Cassia petesiana	12	30.00	2.04
Flacourtia indica	12	30.00	2.04
Diospyros abyssinica	11	27.50	1.87
Warburgia ugandensis	10	25.00	1.70
Ficus vasta	10	25.00	1.70
Combretum collinum	9	22.50	1.53
Albizia grandibracteata	9	22.50	1.53
Vanguera apiculata	9	22.50	1.53
Croton macrostachyus	8	20.00	1.36
Polyscias fulva	8	20.00	1.36
Podocurpusfalcatus	8	20.00	1.36
Sapium ellipticum	8	20.00	1.36
Terminalia sp.	7	17.50	1.19
Grewia ferruginea	7	17.50	1.19
Ficus sycomorus	7	17.50	1.19
Acalipha racemosa	7	17.50	1.19
Securidaca longepedunculata	6	15.00	1.02

Dracaena steudneri	6	15.00	1.02
Vepris dainelli	6	15.00	1.02
Combretum collinum	6	15.00	1.02
Ximenia americana	6	15.00	1.02
Protea gaguedi	5	12.50	0.85
Ficus ovate	5	12.50	0.85
Manilcara butuji	4	10.00	0.68
Vernonia amygdalina	4	10.00	0.68
Lepidotrichilia volkensii	4	10.00	0.68
Chionahshus mildbraedi	4	10.00	0.68
Rhus ruspolii	3	7.50	0.51
Carissa spinarum	3	7.50	0.51
Vernonia auriculifera	3	7.50	0.51
Ficus exasperata	3	7.50	0.51
Vernonia adoensis	2	5.00	0.34
Syzygium guineense subsp.guineensis	2	5.00	0.34
Prunus africana	2	5.00	0.34
Clausena anisata	2	5.00	0.34
Vernonia hymenolepis	2	5.00	0.34
Maytenus gracilipes	2	5.00	0.34
Grewia mollis	1	2.50	0.17
Allophylus abyssinicus	1	2.50	0.17
Grewiamicrocos	1	2.50	0.17
Hyperecum quartinianum	1	2.50	0.17
Echinops macrochactus	1	2.50	0.17
Vanguaria volkensi	1	2.50	0.17
Vernonia wollastonii	1	2.50	0.17
Hippocreteaafricana	1	2.50	0.17
Crepis rueppellii	1	2.50	0.17
Apodytes dimidicata	1	2.50	0.17
Rytigynia neglecta	1	2.50	0.17
	588	**1470.00**	**100.00**

Annex 6: Descending order of IVI for woody species in Aba Sena Natural Forest

Species	Relative Density	Relative Dominance	Relative Frequency	Important Value Index(IVI)	Rank
Ficus sur	4.50	17.75	3.57	25.82	1
Pouteria adolfi-friederici	5.80	8.23	3.40	17.43	3
Terminalia macaroptera	4.35	6.86	3.06	14.27	4
Combretum molle	5.49	3.16	3.57	12.22	5
Ochna holstii	4.20	4.05	3.06	11.31	6
Stereospermum kunthianum	4.35	2.13	3.23	9.71	7
Ficus vasta	0.99	6.77	1.70	9.46	8
Dombeya quinqueseta	4.27	2.43	2.72	9.42	9
Syzygium guineense	2.75	4.09	2.55	9.39	10
Terminalia schimperiana	3.74	2.16	3.06	8.96	11
Mimusops kummel	3.05	1.95	3.23	8.23	12
Celtis africana	2.75	2.14	3.06	7.94	13
Bridelia micrantha	2.21	3.06	2.38	7.65	14
Grewia bicolar	2.67	2.38	2.55	7.60	15
Gardenia ternifolia	3.59	0.55	2.89	7.02	16
Albizia grandibracteata	1.68	3.76	1.53	6.97	17
Cordia africana	2.06	1.74	3.06	6.86	18
Aibizia adianthifolia	1.98	2.45	2.38	6.81	19
Millettia ferruginea	3.05	1.12	2.38	6.56	20
Bersama abyssinica	2.82	0.96	2.72	6.50	21
Warburgia ugandensis	1.07	3.31	1.70	6.07	22
Sapium ellipticum	0.99	3.46	1.36	5.82	23
Maytenus undata	2.44	0.75	2.38	5.57	24
Ficus ovata	0.76	3.88	0.85	5.50	25
Bauhinia toneatosa	2.21	0.85	2.38	5.44	26
Podocurpus falcatus	1.07	2.58	1.36	5.01	27
Phoenix reclinata	1.53	0.14	2.72	4.38	28
Croton macrostachyus	1.45	1.37	1.36	4.18	29
Diospyros abyssinica	1.83	0.40	1.87	4.11	30
Cassia petesiana	1.75	0.14	2.04	3.93	31
Ficus sycomorus	0.76	1.77	1.19	3.72	32
Flacourtia indica	1.45	0.14	2.04	3.63	33
Combretum collinum	1.60	0.24	1.53	3.37	34
Polyscias fulva	1.22	0.35	1.36	2.93	35
Securidaca longepedunculata	1.37	0.42	1.02	2.81	36
Protea gaguedi	1.14	0.47	0.85	2.47	37

Terminalia sp.	0.92	0.31	1.19	2.41	38
Vanguera apiculata	0.76	0.02	1.53	2.31	39
Dracaena steudneri	0.92	0.09	1.02	2.03	40
Grewia ferruginea	0.76	0.04	1.19	1.99	41
Combretum collinum	0.84	0.07	1.02	1.93	42
Vepris dainelli	0.76	0.02	1.02	1.80	43
Acalipha racemosa	0.53	0.03	1.19	1.75	44
Ximenia americana	0.53	0.01	1.02	1.57	45
Ficus exasperata	0.23	0.81	0.51	1.55	46
Manilcara butuji	0.61	0.00	0.68	1.29	47
Vernonia amygdalina	0.46	0.05	0.68	1.19	48
Chionahshus mildbraedi	0.38	0.07	0.68	1.13	49
Lepidotrichilia volkensii	0.38	0.03	0.68	1.09	50
Rhus ruspolii	0.31	0.10	0.51	0.92	51
Carissa spinarum	0.38	0.01	0.51	0.90	52
Syzygium guineense subsp.guineensis	0.23	0.22	0.34	0.79	53
Vernonia auriculifera	0.23	0.01	0.51	0.75	54
Prunus africana	0.23	0.06	0.34	0.63	55
Clausena anisata	0.23	0.01	0.34	0.58	56
Vernonia adoensis	0.23	0.00	0.34	0.57	57
Vernonia hymenolepis	0.15	0.00	0.34	0.50	58
Maytenus gracilipes	0.15	0.00	0.34	0.50	59
Apodytesdimidiata	0.08	0.01	0.17	0.25	60
Hippocretea africana	0.08	0.01	0.17	0.25	61
Vernonia wollastonii	0.08	0.00	0.17	0.25	62
Crepis rueppellii	0.08	0.00	0.17	0.25	63
Hyperecum quartinianum	0.08	0.00	0.17	0.25	63
Grewiamicrocos	0.08	0.00	0.17	0.25	65
Grewia mollis	0.08	0.00	0.17	0.25	65
Echinops macrochactus	0.08	0.00	0.17	0.25	66
Vanguaria volkensi	0.08	0.00	0.17	0.25	67
Allophylus abyssinicus	0.08	0.00	0.17	0.25	68
Rytigynia neglecta	0.08	0.00	0.17	0.25	69
	100.00	100.00	100.00	300.00	

Annex 7: Vegetation of Aba Sena Natural Forest (Photo taken by Tekle, 2018)

Annex 8: Topography of Aba Sena Natural Forest area(Photo taken by Tekle, 2018)