JIMMA UNIVERSITY
COLLEGE OF NATURAL SCIENCE
SCHOOL OF GRADUATE STUDIES
DEPARTMENT OF BIOLOGY

WOODY PLANT SPECIES DIVERSITY AND ABUNDANCE IN GONBISO NATURAL FOREST, BORE DISTRICT, GUJI ZONE, OROMIA REGIONAL STATE, SOUTHERN ETHIOPIA

By

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A Thesis Report Submitted to the Department of Biology, College of Natural Science, School of Graduate Studies, Jimma University for the Partial Fulfillment of the Requirements of the Degree of Masters of Science in Biology.

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Jimma

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Jimma, Ethiopia

Declaration

I, the undersigned declare that this Thesis work is my original work and it has not been presented in other University, Collage or Institutes for a degree or other purpose. All sources of the materials used have been duly acknowledged.

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CONTENTS

Acknowledgement iii

List of Tables viiii

LIST OF FIGURES ix

LIST OF ACRONYMS x

ABSTRACT........ xii

1. INTRODUCTION 1

1.1. Background of the study 1

1.2. Statement of the problem 2

1.3. Objectives of the Study 4

1.3.1. General Objective 4

1.3.2. Specific Objectives 4

1.4. Significance of the Study 4

1.5. Limitations of the Study 5

2. REVIEW OF LITERATURE 6

2.1. Vegetation Types of Ethiopia 6

2.1.1. Moist Evergreen Afromontane forests in Ethiopia 6

2.2. Plant Species Diversity 7

2.2.1. Species Diversity and Richness 7

2.2.2. Diversity indices 8

2.3. Plant Population Structure 8

2.4. Species Abundance, Frequency and Important Value Index 9

2.5. Plant Community Classification and Indicator Species 10

2.6. Regeneration Status of Natural Forest 11

2.7. The Status Plant Species Diversity and Abundance in Ethiopia 11

2.8. Factors Contributing for Destruction of Natural Forests in Ethiopia 12
3 .MATERIALS AND METHODS 14
3.1. Description of the Study Site 14
3.2. Site selection and sampling techniques 15
3.2.1. Reconnaissance Survey 15
3.2.2. Data Collection 15
3.2.3. Voucher Plant Specimen Collection and Identification 16
3.2.4. Environmental and Disturbance Data Collection 16
3.3. Data Processing and Analysis 17
3.3.1. Species Diversity 17
3.3.2. Community Classification 18
3.3.3. Population Structure 18
3.4. Regeneration Status 21
4. RESULTS AND DISCUSSION 22
4.1. Woody Plant Species Composition 22
4.2. Density 22
4.3. Frequency 23
4.4. Basal Area and Important Value Index 26
4.5. Vegetation community classification 28
4.5.1. Description of the Plant Community 33
4.5.2. Species Richness, Species Evenness and Species Diversity of Plant Community Types 35
4.6. Vegetation Structure 36
4.6.1. Vertical Structure 36
4.6.2. Diameter at Breast Height (DBH) 37
4.6.3. DBH Structure of Some of Woody Plant Species 38

4.6.4. Height.......... 40

4.7. Regeneration status of woody species in Gonbiso Natural Forest.......... 42

4.8. Regeneration status of some representative woody plant species of Gonbiso forest.......... 45

4.9. Status of the forest: An implication for conservation 46

4.9.1. Threats for Gonbiso Natural Forest.......... 47

5. CONCULUSION AND RECOMMENDATION.......... 49

5.1. Conclusions 49

5.2. Recommendation 50

REFERENCES 51

APPENDICES

Appendix 1: List of Woody Plant Species Collected from Gonbisoo Natural Forest

(2015)……………………………………………………………………………………..57

Appendix 2: Shannon Species Diversity Index in Decending order………………………...61

Appendix 3: Woody Plant Species with Frequency, relative frequency, density, basal area and relative Dominance in decreasing order, and IVI……………….64

Appendix 4: Density of Woody Plants in Three Life Stages of …………………………… 67

Appendix 5: Location of quadrats in relation to altitude, latitude, aspect and bearing……. 70

List of Tables

Tables **Page**

Table 1: Frequency Classes of Woody Plant Species in Gonbiso Natural Forest…………...24

Table 2: Importance Value Index Class and the Number of Species belonging to each Class…………………………………………………………………………...27

Table 3: List of Species under the Five Priority Classes……………………………………..27

Table: 4 Indicator Values (% of perfect Indication, based on combining Relative Abundance and Relative Frequency) of each species for each of the four groups and the Monte Carlo test (P*) of the significance observed for each Species. (Bold values indicate indicator species at P*<0.05)………………………..30

Table 5: Shannon- Weiner Diversity Index of Communities………………………………..35

Table 6: Regeneration status of woody plants in GNF under three growth stages…………44

LIST OF FIGURES

Figures Page

Figure 1: Map of the Study Area……………………………………………………………..14
Figure 2: Dendrogram..……………………………………………………………………....32

Figure 3a: Anthropogenic Disturbance in each Community…………………………….…....34

Figure 3b: Grazing Levels……………………………………………………………….....35

Figure 4: Vertical Structures of Woody plant Species…………………………………………37

Figure 5: Vertical Structure of Woody Plant Species in GNF…………………………………..38

Figure 6 (a-d): Population Structure of Representative Woody Plant Species at Gonbiso

Natural forest by DBH class ……………………………………………………40

Figure 7: Height class distribution of woody plants in Gonbiso natural
forest…………………………………………………..……………………………………41

Figure 8a-c: Regeneration Status of Some Woody plants……………………………….………..46

Figure 9(a-g): Antropogenic effect …………………………………………………...……47

LIST OF ACRONYMS

BA	Basal Area
CBD	Convention on Biological Diversity
DBH	Diameter at Breast Height
EFAP	Ethiopian Forestry Action Plan
EFAP	Ethiopian Forestry Action Program
EPA	Environmental Protection Authority
ETH	National Herbarium of Ethiopia
FEE	Flora of Ethiopia and Eritrea
GNF	Gonbiso Natural Forest
GPS	Geographical Position System
IBC	Institute of Biodiversity Conservation
IBCR	Institute of Biodiversity Conservation and Research
IUCN	International Union for Conservation of Nature and Natural Resources
LULCC	Land Use Land Cover Change
NAP	National Action Plan
NBSAP	National Biodiversity Strategy and Action Plan
RD	Relative Density
RDO	Relative Dominance
RF	Relative Frequency
SCBD	Secretariat of the Convention on BiologicDiversitys

ABSTRACT

Forest ecosystems provide numerous ecological services and economic benefits to many national economies in the world. Gonbiso Natural forest is one of the few remaining Evergreen moist Afromontane forests in the southern part of Ethiopia. Woody species diversity and abundance, species composition, structure and regeneration patterns of this forest were studied to generate information essential for formulating feasible management options for the forest. Vegetation data were collected from 50 quadrates of size 20 m x 20 m, 10 m x10 m and 5 m x 5 m for tree/shrub, sapling, and seedling, respectively, laid systematically along transects. A total of 62 woody species belonging to 55 genera and 40 families were recorded. Rosaceae with 4(10.8%) species each was the most diverse families, followed by Rubiaceae, Euphorbiacea, Rutiaceae, Araliaceae, Asteraceae and Oleaceae with three (8.1%) species each. Tree/shrub, sapling and seedling densities were 610.5, 872.5 and 1416 individuals/ha respectively. About 35.9% of the importance value index was contributed by Allophyllus abysinicus, Croton macrostachyus, Schefflera abyssinica, Syzygium guineense, Millettia ferruginea and Dombeya torrida. Vegetation classification resulted in four plant communities: Syzygium guineesse-Ricinus communis, Dombeya torrida- Scheffera abyssinica, Millettia ferruginea- Maytenus arbutifola, and Solanum incanum- Hagenia abyssinica. Regeneration status of all the woody plant species was categorized as 'Good' (19.4%), 'Fair' (38.7%), 'Poor' (17.7%), 'None' (22.6%) and 'New' (1.6%). The study is expected to provide valuable and adequate information that are essential for understanding the current situation of the forest.

Key words/Phrases: Plant Community, Plant Population Structure, Species Abundance Diversity, and Woody Plants,

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Forest ecosystems provide numerous ecological services and economic benefits to many national economies in the world. Forests worldwide are known to be critically important habitats in terms of the biological diversity they contain and ecological functions they provide (SCBD, 2001). Forest gives important environmental benefits by providing carbon sink/ carbon storage service, watersheds protection services (protect soil erosion and flooding) and providing habitats for a large number of animals (Nune *et al*., 2010). Forest also serves as a source of food, household energy, construction and agricultural material, tourism and recreation values and medicines for both people and livestock (Vivero *et al.*, 2005).

For many people and economic planning authorities, however, forest ecosystems should meet the immediate needs of mankind such as employment, food, and shelter. Therefore, conservation for ecological services is usually placed in the second pecking order of action. It is not surprising that industrial development leads to large-scale clearance of forested or wooded areas (Steininger *et al.,* 2001). Due to extreme loss of forests, the earth has evidenced a considerable warming during the last three decades (Thomas *et al.,* 2004).

Recent studies on the situation of forests in Ethiopia show that most of the forests of the country have disappeared as a result of continuous deforestation, and deforestation continues unabated at a very alarming rate. Although there is controversy over the precise figures of the former forest cover in Ethiopia, historical sources indicate that some 35-40% of the land area might have been once covered with forests (EFAP, 1994). With the inclusion of savannah woodlands the estimate rises to some 66% of the country. In the early 1950's, the forests that remained covered 19 million hectares or 16% of the land area and in the 1980's coverage was reduced to 3.6%, by 1989 to 2.7 % (Gessesse, 2010).

Clearance of natural vegetation to meet the demands of an ever increasing human population has been an ongoing process. As a result of increasing demand for agricultural land that resulted in extensive forest clearing for agricultural use, the increasing livestock population resulted in overgrazing, and an increasing demand for fire wood and charcoal resulted in exploitation of existing forests for fuel wood, and construction materials (Soromessa *et al*., 2004).

Successful natural resource management and conservation are usually hindered by lack of or inadequate information to guide decision-making (Hunt, 2002). Changes in vegetation usually manifest themselves in social, economic, ecological, and cultural impacts (Okoti *et al.,* 2004). There is a need to monitor vegetation and land-use changes in order to mitigate their impacts through conservation interventions. Botanical assessments such as floristic composition, species diversity and structural analyses studies are essential for providing help information on species richness of the forests, useful for forest management purpose and in understanding forest ecology and ecosystem functions (Pappies *et al.,* 2010).

Similarly studies on species diversity and abundance of forests are essential for providing adequate information needed for guiding decision-making on forest management and conservation, and monitoring vegetation and land-use changes in order to mitigate their impacts through conservation interventions. Such studies are also essential for understanding forest ecology and ecosystem functions, identifying economically important plants, and protecting threatened plant species.

1.2. Statement of the problem

Ethiopia is a country of diverse plant species forming the line share flora of 6200 species out of the total floral species of 7850 in East Africa (IBC, 2010). According to (Kelbessa *et al.*, 1992) the country is an important regional center for biological diversity due to its wide ranges of altitude, great geographical diversity with high and rugged mountains, flat-topped plateaus and deep gorges, incised river valleys and rolling plains.

Because of its geographical position, ranges of altitude, rainfall pattern and soil variability, Ethiopia, has an immense ecological diversity and a huge wealth of biological resources (IBC, 2007). These topographic and altitudinal variation helped the emergence of wide ranges of habitats that are suitable for the evolution and survival of various plant and animal species (Zeleke, 2003). The Flora of Ethiopia and Eritrea harbors about 6000 higher plant species with 10% endemism (Kelbesa *et al.,* 1992). Furthermore, woody plant species in the Flora of Ethiopia and Eritrea was estimated to be 1100; out of these about 300 are tree species (Teketay *et al.,* 2000).

However, these biologically rich resources of Ethiopia are vanishing at an alarming rate due to extensive deforestation (Lemenih and Teketay, 2006; Didita *et al*., 2010). Vegetation resources in all areas of the country in general and in fragmented landscapes in particular , especially forests, are declining at alarming rate due to increased population (with growth rate 3%) followed by deforestation and land degradation (IUCN, 2006).

Due to the continuing encroachment, it is highly probable that the present fragmented forests in the highlands of Ethiopia are much more impoverished in terms of floristic diversity than the vegetations which once occupied the same site (Moges and Reddy, 2013). Loss of forest cover and biodiversity due to human-induced activities was a growing concern in many parts of the world (Senbeta and Teketay, 2003), because loss of such forest resources would have great implication for the environment, biological diversity and socio-economic setup of the communities (SCBD, 2001). Ecological and environmental problems such as soil degradation, soil erosion and alteration of natural resources are just some of the negative effects resulting from the destruction of these habitats (Hundera *et al*., 2007).

In the study area (Gonbiso Natural forest of Bore district), unfortunately, no studies have been conducted on woody plant species. Thus, it is important to conduct studies on floristic composition, population structure, and diversity and abundance of woody plant species. The central intent of this study was assessing the diversity and abundance of woody plant species in Gonbiso natural forest of Bore district, in Guji zone, Oromia Regional state, South Ethiopia.In order to accomplish the ultimate objective of the study, assessment of the plant communities, the diversity and abundance of woody plant species, and the level of disturbance, as well as investigation of the population structure of woody plant species of the forest were made with particular focus to Gonbiso natural forest of Bore District, Guji zone, Oromia Regional state, South Ethiopia.

Research Questions

The following research questions were forwarded to be answered in the process of the study.

- ❖ What do the diversity and abundance of woody plant species of the forest look like?
- ❖ What are the plant community types in the study area?
- ❖ What does the population structure of woody plant species of the forest look like?
- ❖ What does the regeneration status of woody plant species of the forest look like?

1.3. Objectives of the Study

1.3.1. General Objective

The general objectives of this study was to investigate and document the diversity, abundance of woody plant species in Gonbiso natural forest of Bore district, Guji zone, Oromia Regional state, Southern Ethiopia.

1.3.2. Specific Objectives

- To assess the diversity and abundance of woody plant species of the forest,
- To investigate plant communities of the study area,
- To investigate the population structure of woody plant species of the forest,
- To assess the regeneration status of woody plants species of the forest,
- To assess factores for destruction of woody plants of the forest,

1.4. Significance of the Study

This study aims at investigating the diversity and abundance of woody plant species in Gonbiso natural forest of Bore district, Guji zone, Oromia Regional state, Southern Ethiopia, so as to determine the diversity and abundance, the population structure of woody plant species, and plant communities of the study area. As a result, it is believed to have a number of theoretical and practical contributions. The study is expected to provide valuable and adequate information that are essential to the understanding of the current situation of the forest. It provides document that serves as source of data for further studies. The findings of the study are also believed to have profound contribution for understanding the forest ecology and ecosystem functions.

Moreover, the study creates common awareness among the concerned bodies at various levels including the local community. This might help develop a sense of ownership of the local people so that the local communities take responsibility for the management and conservation, and become beneficiaries of the effective management of the forest.

1.5. Limitations of the Study

Lack of inadequacy budget as well as accessibility problems were among the major limitations confronted to the researcher of this study.

CHAPTER TWO

2. REVIEW OF LITERATURE

2.1. Vegetation Types of Ethiopia

Many scholars have studied and described Ethiopian vegetation. Based on their results, the vegetation types of Ethiopia have been grouped in to eight general categories. These are Desert and Semi-desert Scrubland, *Acacia*-*Commiphora* Woodland, Moist Evergreen Montane Forest, Lowland Semi-evergreen Forest, *Combertum*- *Terminalia* Woodland, Dry Evergreen Montane Forest, Afro alpine, and Sub-Afro alpine Vegetation, and Riparian and Wetland Vegetation (Zerihun *et al.,* 1989). Some studies (e.g. Hundera *et al*., 2007; Hundera and Deboch, 2008; Kelbessa and Soromessa, 2008; Feyera, 2010; Lisanework and Mesfin, 1989; Yeshitela and Bekele, 2002) provided general description of the vegetation types and their floristic composition in different parts of Ethiopia. A recent publication indicated that there are twelve major vegetation types in Ethiopia. These major vegetation types include; Desert and Semi desert scrubland Forest; Acacia - Commiphora woodland and bush land; Wooded grassland of the Western Gambela region; Combretum - Terminalia woodland and wooded grassland; Dry Evergreen Afromontane Forest and grassland complex; Moist Evergreen Afromontane Forest and bush land; Transitional rain Forest; Ericaceous belt; Afro-alpine belt; Riverine vegetation; Fresh - water lakes; and Salt Lakes vegetation (Friis *et al.,* 2010).

2.1.1. Moist Evergreen Afromontane forests in Ethiopia

Afromontane forests in Ethiopia are generally cooler and more humid than the surrounding lowland although the classification of forests as “moist” or “dry” and the criteria followed to define these limits are loose. Logan (1946) used altitudinal variations to distinguish between what he called ‘climatic moist woodland’ and ‘climatic dry woodland’ on the Ethiopian plateau. Gonbiso forest is one of the moist evergreen afromontane forests (Bore District Forest and Wild Life Office, 2015).

Characteristics of species in Afromontane area of Ethiopia include *Podocarpus falcatus*, *Prunus africana*, *Hagenia abyssinica, Juniperus procera,* and *Olea* sp. The moist Evergreen Montane Forest comprises the humid forest in the southeastern plateau, Harenna Forest, (Lissanework and Mesfin, 1989) and Mana Angetu Forest (Lulekal *et al.,* 2008) and highland forests of the country mainly the southwest forests. The Moist Evergreen Montane Forest of west and southwest Ethiopia occurs between 1,500−2,500 m a.s.l. in Wollega, Illubabor and Kefa. The average annual temperature and rainfall of this vegetation type is 18−20°C, and 1,500 and 2,000 mm, respectively. The maximum rainfall is from April to October (Friis *et al.,* 1982; Friis 1992).

Moist evergreen montane forest ecosystem is the most diverse ecosystem in composition, structure and habitat types (NBSAP, 2005). The common species in these forests include *Pouteria altissima*, *Pouteria adolfi-friederici*, *Trilepsium madagascariense*, *Morus mesozygia*, *Mimusops kummel*, *Podocarpus falcatus*, *Coffea arabica*, *Galiniera saxifraga*, *Syzygium guineense* ssp*. afromontanum*, *Apodytes dimidiata*, *Prunus africana*, *Albizia gummifera*, *Albizia schimperiana*, *Croton macrostachyus*, *Cassipourea malosana*, *Ekebergia capensis*, *Euphorbia ampliphylla*, *Ficus vasta*, *Maesa lanceolata*, *Teclea nobilis* and *Bersama abyssinica* (Kelbessa and Soromessa *et al.,* 2008).

2.2. Plant Species Diversity

According to Van der Maarel (2005) species diversity refers to the number of species found in a given area. Species diversity has been identified as one of the key indices of sustainable land use practices and considerable resources are expanded to identify and implement strategies that will reverse the current decline in biodiversity at local, regional and international scales. Species diversity is described based on two concepts (factors), the total number of species in the community (Species richness) and the relative abundance of species (Species evenness) within the sample or community

2.2.1. Species Diversity and Richness

Species diversity can be viewed from different perspectives: alpha, beta and gamma diversity. Alpha diversity refers to the diversity of species within a particular habitat or community. Beta diversity is a measure of the rate and extent of change in species along a gradient from one habitat to another. It is between habitat diversity that measures turnover rates. Beta diversity is sometimes called habitat diversity. Gamma diversity is the diversity of species in comparable habitats along geographical transect and it depends on the alpha and beta diversity (Kent and Coker, 1992).

Moreover, these diversity indices provide information about community composition. Wellbeing of ecological systems can be measured by community diversity indices. Among many of the species diversity indices, diversity and evenness are often calculated by using Shannon diversity index. It is the most widely used index because of its power to combine species richness with evenness better than other indices (Kent and Coker, 1992).

Species richness refers to the total number of species in a community while evenness is the relative abundance of species within the sample or community (Kent and Coker, 1992). The two components can be examined independently or combined in some form of index. Generally, these 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. Diversity Indices

Biological diversity can be quantified in different ways. A diversity index is a mathematical measure of species diversity in a community. The two main factors taken into account when measuring diversity are richness and evenness. So that diversity index, must be sensitive to both factors, thus must also be sensitive to the different number of species in two or more communities (Mueller-Dombois and Ellenberg, 1974).

2.3. Plant Population Structure

Population structure is defined as the distribution of individuals of each species in arbitrarily diameter–height size classes to provide the overall regeneration profile of the study species (Peters, 1996; Shibru and Balcha, 2004). Population structure is extremely useful tool for orienting management activities and, perhaps most important for assessing both the potential of a given resources and the impact of resource extraction. Information on population structure of a tree species indicates the history of the past disturbance to that particular species and the environment; and hence, used to forecast the future trend of the population of that particular species (Peters, 1996).

Analyses of population structure have then something to do with the future management of the key and untapped resources of the dry land of Ethiopia. Information on population structure helps to respect the healthy regeneration of the species under utilization (Gebrehiwot, 2003). The population structure of a given species can be roughly grouped in to three types: Type I, II and III. Type I, shows the case in which diameter/height size class distribution of the species displays a greater number of smaller tree than big tree, and almost constant reduction in number from one size class to the next (Peters, 1996; Shibru and Balcha, 2004). Such patterns skewed to a reversed J-shaped distribution in forest are considered to have a favorable status of regeneration and recruitment; and hence, stable and healthy population (Fisaha *et al.,* 2013).

Type II, is characteristic of species that show discontinuous, irregular and/or periodic recruitment. In this type, the frequency exhibited; for instance, in diameter/height size class causes discontinuities in the structure of the population as the established seedling and sapling grow in to larger size class. Type III reflects a species whose regeneration is severely limited for some reasons (Peters, 1996). Hence, knowledge about the category in which our study species fall is important issue before planning to utilize the resources.

2.4. Species Abundance, Frequency and Important Value Index

Abundance is the number of plant per unit area. It is the number of individual plants of a given species per unit area. Measurement of plant abundance requires the counting of individual plants by species in a given area. It can be used to show spatial distribution and ranges over time (Van der Maarel, 2005).

Frequency is the proportion of quadrates in which a species occurs. It is a measure of the occurrence of a given species in a given area. Frequency indicates how the species are dispersed and is an ecologically meaningful parameter. According to Kent and Coker (1992) it can give an approximate indication of the homogeneity of the quadrates under consideration**.**

Species Importance Value Index (IVI) permits a comparison of species in a given location and reflects the dominance, occurrence and abundance of a given species in relation to other associated species in an area (Kent and Coker, 1992). Generally, to develop conservation strategy and plan, species importance value index is a good index for summarizing vegetation characteristics and to rank species for management and conservation practices and to prioritize them.

2.5. Plant Community Classification and Indicator Species

Vegetation classification has been widely used in plant as a necessary tool to produce some order in to a collection of facts and enables one to communicate description and ideas on the relationship about the type of vegetation recorded and make comparisons with similar or dissimilar samples from elsewhere. It can be defined as the collection of plant species growing together in a particular location that show a definite association of affinity with each other (Kent and Cooker, 1992). Plant community understood as combination of plants that are dependent on their environment, influence one another, and modify their environment. The floristic compositions of vegetation include all species occurring within a plant community. However, most communities consist of many different species which are not particular to discover all species within a community (Mueller-Dombois and Ellenberg, 1974).

Indicator species are whose status provides information on the overall condition of the forest and gives information about other species in the forest. They reflect the quality and changes. In the environmental condition as well as other aspects of the community composition. Moreover, their presence or absence, or their relative wellbeing in a given environment is indicative of its ecosystem. There is no fixed size for a community. They can range from very small size to variable expanses of grassland or forest (Peters, 1996).

2.6. Regeneration Status of Natural Forest

Natural regeneration is the process by which tree and woodlands are established from seeds produced and germinated in situ. It usually relates to the restocking of existing woodland but also includes the natural colonization of previously un-wooded sites. In some circumstances natural regeneration may be more desirable than planting, for example; it can conserve local genotype and also create more structural diversity within the site (Harmer, 1994). Regeneration assessment is an important part of forest survey which serves in evaluating stocking, competition problems and the composition of the forest to make a decision whether the area is well established with the desired species and less competition (Tenkir, 2006)

Studies on population structure and density of major canopy tree species can help to understand the status of regeneration of species and, thereof, management history and ecology of the forest. Plant population structure shows whether or not the population has a stable distribution that allows continuous regeneration to take place. If regeneration was taking place continuously, then the distribution of species cohorts would show reverse J shape curve, which is an indicator of healthy/good regeneration. Information on tree seedling ecology can provide options for forest development through improvement in recruitment, establishment and growth of the desired species (Tesfaye *et al.,* 2010).

2.7. The Status of Plant Species Diversity and Abundance in Ethiopia

Diversity is unevenly distributed over the surface of the earth (Wana, 2009). The most conspicuous spatial pattern of species diversity is a latitudinal gradient of decreasing richness of species from equator to poles (Willig *et al.,* 2003). Some studies show that about 35%−40% of the land area of Ethiopia was covered by forest vegetation in the 1990s (EFAP, 1994). Since then, forests have been destroyed at an alarming rate and the area covered by forests by 1998 was only 2.4 percent (EPA, 1998).

Factors such as rising demand for timber products, conversion of forest land to agricultural land, and expanding population pressure are responsible for the decline in the forest cover of the country (EPA 1998). Even though Ethiopia is rich in biodiversity with high endemism and most of her forests have provided socio-economic benefits and ecological functions for long periods of time, many species are now being threatened or are endangered or locally extinct. This is due to habitat destruction and fragmentation, and over-exploitation of wildlife and habitats (Teketay, 2001).

According to Bekele (2011) the Ethiopian vegetation is highly influenced by expansion of agriculture practices, which necessarily lead to land degradation and to a decline in biological diversity, is associated with increase number of population. The growing human population and the demand for natural resources have put great pressure on the biodiversity wealth of the world through deforestation, habitat fragmentation, and overexploitation of species. Consequently, unprotected areas with heavy human pressures are expected to be degraded leading to diminishing biological diversity and, as a result, are typically ignored by conservation agencies.

Alelign *et al.,* (2007) revealed that the unsustainable exploitation of the forest by the local communities has critically affected species evenness of the woody plants and population structure of the forest as evidenced by the very low density of not only many species but also the forest as a whole. High dependency of the people on wood from the forest for generation of income, high population density and shortage of land coupled with moisture stress are the major problems that could pose serious threat to the forest resources.

2.8. Factors Contributing for Destruction of Natural Forests in Ethiopia

Ethiopia has the fifth largest floral diversity in tropical Africa (Didita *et al.,* 2010). According to (Vivero *et al.,* 2006) the Ethiopian highlands contain a rich floral and high level of endemism. However, these biologically rich resources of Ethiopia are vanishing at an alarming rate due to extensive deforestation (Didita *et al*., 2010).

Deforestation and land conversion for agriculture, grazing, and demand for household energy have decimated the vegetation cover of the country (Ezra, 2001). Growth in human population density and rural poverty further reinforced the process of biodiversity loss via land conversion and increased demand for household energy (Gessesse & Christiansson, 2008). According to IUCN’s Red List Categories, Ethiopia possessed one endangered, 21 vulnerable, one lower risk conservation dependent, 30 near threatened (includes lower risk/near threatened), one data deficit and three least concern (includes lower risk, least concern) plant species (IUCN, 2006).

Although several factors drive natural forest destruction in Ethiopia, agricultural land expansion triggered by increasing human population is probably the dominant force (Didita *et al*., 2010). The traditional diversification of farmlands, which has been the source of sustenance in rural Ethiopia, has largely been abandoned (Worku, 2009). The land use system is associated with the conversion of forested and marginal lands to agricultural lands, resulting in massive environmental degradation and a serious threat to sustainable agriculture and forestry (Kippie, 2002).

The increasingly intensified forms of land use have had a wide range of effects on biotic and landscape diversity, and it would be an oversimplification to assume that this has resulted in a uniform decline in biodiversity. Land use/land cover change (LULCC) is the main contributor to global environmental change such as greenhouse gas emissions, the earth's reflectivity (temperature) and water cycles including local and regional precipitation regimes (Geist, 2006). It also has a negative consequence on the provision of ecosystem services through watershed degradation, soil erosion and sedimentations (Jones *et al.,* 2001).

CHAPTER THREE

3 .MATERIALS AND METHODS

3.1. Description of the Study Site

The study was conducted on Gonbiso Natural Forest, located in Bore district, Guji Zone of Oromia Regional National State. It is located at a distance of 415 kilometers from Addis Ababa. According to Bore District Forest and Wild Life Office (2015) geographically, the study site is located in between 4^0 17’ 176’’N to 4^0 18’ 799’’N latitude and longitudinally, between 40^0 46’ 722’’E to $40^0$48’ 938’’E. The climate of the study area is Cool zone (Dega), its altitudinal range is between 2291-2422 meters above sea level. The area receives a mean annual rainfall of 2200 mm. and, the temperature of the area ranges from 15-16 ^{0}C (Bore District Forest and Wild Life Office, 2015).

The total area of the forest is 435.44 hectares. This total area of the forest is divided in to two blocks.The first block of the forest is 250.49 hectares, while the second block sized 184.95 hectares (Bore District Forest and Wild Life Office, 2015)**.**

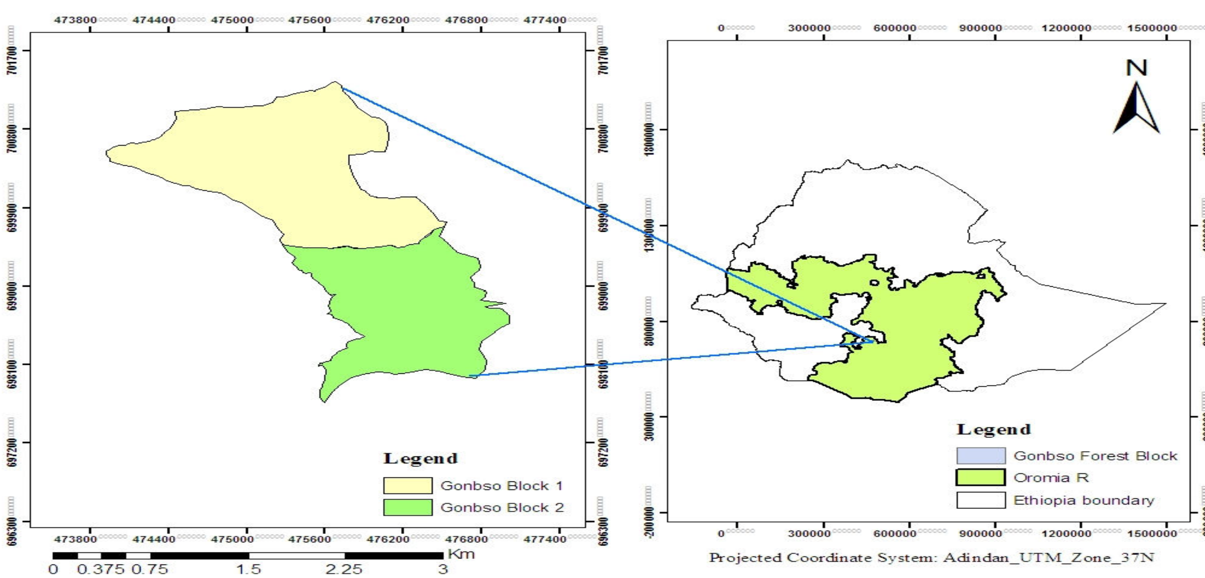


Figure 1: Map of the Study Area

3.2. Site Selection and Sampling techniques

3.2.1. Reconnaissance Survey

Reconnaissance survey was conducted in mid November, 2015 to have familiarity with the vegetation, topography of the area, identify direction of the transect line; have fell for altitudinal gradients and to familiarize with woody plant species of the area. A proportional number of quadrates were taken from each of the block using systematic random sampling method. A total of 50 (29 quadrates from block 1 and 21 quadrates from block 2 were taken

3.2.2. Data Collection

In order to collect the necessary data for the study, observation and field survey were employed. To investigate the species composition and density of woody plants, line transects, which are laid down following the eight aspects of the site (north, south, east, west, northeast, northwest, southeast and southwest) starting from the highest altitude towards the lowest, were used. Sample quadrates measuring 20 x 20 m for tree/shrub, 10 x 10m for sapling, 5 x5m for seedling were laid down along transects at a distance of 100m from each other using measuring tape and a Silva compass.

A total of 50 quadrates (7 quadrats in west aspect; 6 quadrants in south west aspect; 6 quadrates in southeast aspect; 6 quadrates in east aspect; 4 quadrates in north aspect; 7 quadrates in south aspect; 7 quadrates in northwest; and 7 quadrates in northeast) aspect were used for the census of wood plant species in the site. The quadrates on the transect lines were located systematically at a distance of 100 m from each other using GPS and Silva compass but the initial quadrate were selected randomly.

The quadrates were delineated using polyethylene strings tied around four wooden pegs inserted into the soil at the four corners of the quadrants. In each quadrate, identity, number, height and diameter (DBH) of individuals (with $\geq$ 2 cm) of all woody plants were recorded. Height was measured by hypsometer (type 65, Swedish made), while diameter of small and big trees was measured by using a caliper and diameter tape, respectively. The aspect, altitude and slope of each quadrant were measured using a Silva compass (type 15T), Altimeter and Clinometers, respectively.

For the purpose of analyzing population structure of the woody species, individuals of the same species were categorized into eight diameter and ten height classes. Seedlings and saplings of woody species that regenerated both from seeds and coppices were recorded based on the method supported by Kelbessa and Soromessa (2008).

Canopy and ground cover in each quadrate were evaluated subjectively and grouped into 3 classes: (1) less than 33% cover (open canopy), (2) 33% to 66% canopy cover (medium shade) and (3) > 66% canopy cover (high shade canopy). Similarly, the ground cover was classified into 3 classes: 1= good cover with deep organic layer, 2 = intermediate cover with average organic layer and 3= thin cover or exposed soil.

3.2.3. Voucher Plant Specimen Collection and Identification

Duplicate voucher specimens of woody plants species of the forest were collected and numbered by recording their local name on field note book with the help of local communities; described using herbarium sheet format, pressed and dried. Identification of the plants was performed both in the field using the book by Bekele (2007). Plant specimens encountered in each quadrat were collected, pressed, verification and deposited at Jimma University herbarium, Biology Department.

3.2.4. Environmental and Disturbance Data Collection

The environmental variables used in this study were elevation (measured by GPS and Altimeter), slope (measured with Clinometers), the extent of disturbance in particular human cut stumps of woody plants were identified by involving knowledgeable persons from the local communities (Alelign *et al,.* 2007) and grazing (subjectively rated as 1 = no grazing, 2 = moderately grazing, and 3 = highly grazing) was considered (Woldemichael *et al.,* 2010).

3.3. Data Processing and Analysis

Vegetation data entry form was developed using Microsoft access application. Subsequent analyses of the data were performed using the same application. Graphs were drawn using excel spread sheets the number of individuals of each woody species per hectare was calculated from the total number of the species recorded in the 50 quadrates measuring a total area of 2 ha, 1 ha, and 0.5 ha for tree/shrub, sapling and seedling respectively.

3.3.1. Species Diversity

Diversity indices measure the degree of uncertainty that is if the diversity is high in a given habitat, the certainty of observing a particular species is low. They are simple mathematical expressions that summarize a lot of data recorded in one or sets of figures. To compare diversity within each species calculated richness and Shannon-Wiener's index (Shannon-Wiener's index). The Shannon index and Simpson's index of diversity, which combine species richness with relative abundance, are widely used in species diversity studies The Shannon index expresses the relative evenness or equitability of species. (Kent and Coker,1992).

The species richness of the native woody plants was calculated by using the following methods:

I. Species Richness is a biologically appropriate measure of alpha (α) diversity and is usually expressed as number of species per sample unit (Kent and Coker,1992)

II. Diversity index**:** Diversity index was **c**alculated according to Shannon-Wiener (1949) by using the following formula:

$$H' = -\sum_{i=1}^{s} \text{pi lnpi}$$

Where, H'= Shannon diversity index;

Σ= Summation symbol;

S = the number of species;

Pi = the proportion of individuals or the abundance of their species (Expressed as a proportion of the total cover);

L n = log base n (natural logarithm)

I.Evenness (Equitability)

$$J = H'/ H'_{max}$$

Where; **J** = Evenness,

H' = Shannon-Wiener diversity index, and

H'max = **lns**

where **s** is the number of species.

The higher the value of **J,** the more even the species is in their distribution within the community and equitability assumes a value between 0 and 1 with 1 being complete evenness. Similarly, the higher the value of **H',** the more diverse the community or the quadrates are.

3.3.2. Community Classification

Hierarchical cluster analysis in PC-ORD for windows version 5.31 (McCune and Mefford, 1999) was used to classify the vegetation in to plant community types following (Senbeta and Teketay, 2003; Weldemariam, 2003). The analysis was based on the abundance data of the species (number of individuals). The indicator species Analysis was used to compare the species present in each group. The identified plant community types or groups were tested for the hypothesis of no difference using Multi-response Permutation procedure (MRPP). A species is considered as an indicator of a group when its indicator value is significantly higher at $p < 0.05$ (Weldemariam, 2003). The plant community types were named after two dominant indicator species selected the relative magnitude of their indicator values.

3.3.3. Population Structure

The structure of the vegetation was described by using frequency distributions of DBH and IVI. Tree or shrub density and basal area values were computed on hectare basis. IVI were computed for dominant woody species based on their relative density (RD), relative dominance (RDO) and relative frequency (RF) to determine their dominance (Kent and Coker, 1992).

Species structure (height, frequency, density, abundance, basal area, stem numbers/ha and importance value index) were computed from the quadrate data. The importance value index was calculated as a sum of relative density, relative frequency and relative dominance. All the woody species were grouped into five IVI classes (1 > 30; 2 = 20.1–30; 3 = 10.1–20; 4 = 1–10; and 5 < 1) based on their IVI values by following (Shibru & Balcha, 2004).

(a) Height

Eight DBH classes (cm) with DBH ≥ 2 cm and height ≥3m were formed. Based on this, woody were categorized into eight DBH classes (cm): 1= 2-10; 2= 10.1-30; 3= 30.1-50; 4=50.1-70; 5= 70.1-90; 6= 90.1- 110; 7= 110.1- 130 and 8≥130. In terms height, they were categorized in to ten height classes: 1= 3-6; 2= 6.1- 9; 3= 9.1-12; 4= 12.1-15; 5=15.1-18; 6= 18.1-21; 7= 21.1-24; 8= 24.1-27; 9= 27.1-30 and 10≥30 following (Kelbessa and Soromessa, 2008)

(b) Frequency (%)

This term refers to the degree of dispersion of individual species in an area and usually expressed in terms of percentage occurrence. It was studied by sampling the study area at several places at random and recorded the name of the species that occurred in each sampling units. It is calculated by the equation:

$$\text{Frequency} = \frac{\text{Number of Quadrates in which species occurred}}{\text{Total Number of Quadrates Studied}} \times 100$$

According to their total frequency expressed as percentage, species were grouped in to the following five frequency classes following (Shibru and Balcha, 2004): A=81-100, B=61- 80, C=41-60, D=21-40, E=0-20.

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

(C) Density

Density is an expression of the numerical strength of a species where the total number of individuals of each species in all the quadrates is divided by the total number of quadrates studied. Density of a species is the number of individuals per hectare. Density was calculated by the equation:

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrates}}{\text{Total number of quadrates studied}}$$

Relative Density was calculated by the equation:

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

$$\text{That is, Relative Density} = \frac{\text{Density of Species A}}{\text{Total Density of all Species}} \times 100$$

(d) Abundance

- It is the study of the number of individuals of different species in the community per unit area.
- By quadrates method, samplings are made at random at several places and the number of individuals of each species was summed up for all the quadrates divided by the total number of quadrates in which the species occurred. It is represented by the equation

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrates}}{\text{Total number of quadrates in which the species occurred}}$$

(e) Basal area

$BA=\frac{\pi d2}{4}$ (BA) is the area outline of a plant near ground surface. It is the cross-sectional area of tree stems at DBH. Generally, it is a measure of dominance, where the term 'dominance' refers to the degree of coverage of species as an expression of the space it occupies at ground level (Muller- Dombois and Ellenberg, 1974) and calculated by using the following formula:

Where, BA= Basal Area in m^2 per hectare

d= diameter at breast height (m)

π= 3.14.

Dominance was calculated by the equation:

$$\text{Dominance} = \frac{\text{Total Basal Area}}{\text{Area Sampled}}$$

Relative Dominance was calculated by the equation:

$$\text{Relative Dominance (RDO)} = \frac{\text{Total basal area of all individuals of a species}}{\text{Total basal area of all species}} \times 100$$

(f) Important Value Index (IVI**)** was computed using the following formula:

IVI = Relative Density (abundance) + Relative Dominance (basal area) + Relative Frequency.

3.4. Regeneration Status

The number of individuals of each tree/shrub, sapling and seedling species per hectare was calculated from the total number of individual species recorded from the sampled area. The regeneration status of the forest was assessed based on phytosociological data which were surveyed from the sampled area in the following categories (Chauhan *et al*., 2008)

Good - if presence of seedling > sapling > mature strata;
Fair - if presence of seedling > sapling < mature strata;
Poor- if a species survive only in the sapling stage, but not as seedling (even through saplings may be less than, more than, or equal to mature);
New – if species has no mature, but only sapling and/ seedling stage (Chauhan *et al*., 2008).
None- if species is absent both in sapling and seedling stages

CHAPTER FOUR

4. Results and Discussion

4.1. Woody Plant Species Composition

A total of 62 species belonging to 55 genera and 40 families were recorded in Gonbiso Natural forest. As can be seen in appendix 1, Rosaceae was the most diversfied families contributing 4 (10.8 %) species each. The families were followed by Rubiaceae, Euphorbiaceae, Rutiaceae, Araliaceae, Asteraceae and Oleaceae each of which contributing 3 (8.1%) species to the total. Acanthaceae, Celastraceae, Boraginaceae, Fabaceae, Flacourtiaceae, Anacardiaceae and Solenaceae were the third diversfied families each represented by 2 (5%) species, while the remaining 22 (59.5%) families were represented by one species each (Appendix 1). The overall Shannon-Wiener diversity and evenness of woody species of Gonbiso natural forest were 3.65 and 0.88, respectively (Appendix 2). Most of the newly appeared plants were small sized woody plant species indicating secondary succession after disturbance.

The diversfied of Rosaceae and Asteraceae could be attributed to their efficient and successful dispersal mechanisms and adaptation to a wide range of ecological conditions (Kelbessa and Soromessa, 2008). Similarly, Rosaceae and Asteraceae are the two diversfied families in Gonbiso forest. However, Poaceae was not recorded as diversfied family (only represented by a single woody species, (Table 1). The expected reason behind reduction of number of Poaceae is due to the fact that this study focused only on woody species and most grasses are herbaceous.

4.2. Density

The total density of mature tree/shrub, sapling and seedling of Gonbiso natural forest was 610.5ha^{-1}, 872.5ha^{-1} and 1,416ha^{-1}, respectively. Tree/shrub species which exhibit highest density were *Millettia ferruginea (58.8 individuals ha^{-1}), Domboya torrida (43.5 individuals ha^{-1}), Croton macrostachys (32 individuals ha^{-1}), Allophylus abyssinicus (26.5 individuals ha^{-1}), Syzygium guineense (26 individuals ha-^{1}), Maytenus arbutifolia (22 individuals ha^{-1}), Rubus apetalus (21 individuals ha^{-1}), Bersama abyssinica (16. 5 individuals ha^{-1}), Teclea nobilis (16* *individuals ha^{-1}), Maytenus undata (16 individuals ha^{-1}), Solanum incanum (15.5 individuals ha^{-1}), Discopodium penninervium (15 individuals ha^{-1}),* and *Vernonia leopoldii (15 individuals ha^{-1}),* which account for about 52.98 % of the total density in the forest. *Ficus vasta* and *Olea europaea* were not represented in their mature stages (Appendix 4).

As compared to results of studies conducted on other forests, the results of this study show that the diversity of Gonbiso natural forest is less than that of Bale mountains national park (898 individuals ha-[1]) (Yineger *et al.,* 2008), much less than Zegie Peninsula forest (3318 individuals ha-[1]) (Alelign *et al.,* 2007) and Dodola forest (1293 individual ha-[1]) (Hundera, *et al.,* 2007). The probable reasons for the variation may be due to high pressure of anthropo- genic disturbance, where large and medium-sized trees have been systematically removed.

The density of sapling was dominated by the following species in descending order, *Maytenus arbutifolia (122 ha^{-1}), Teclea nobilis (66 ha-^{1}), Bersama abyssinica (44.5 ha^{-1}), Canthium crassum (44 ha^{-1}), Maytenus undata (43 ha^{-1}), Vebris dainellii (32 ha^{-1}), Ilex mitis (30 ha^{-1}), Justica schimperiana (30 ha^{-1})* and *Rubus apetalus (26 ha^{-1})* which accounted about 50.1% of the total density of the forest. Out of the total woody plants 30.6% were not represented by their sapling (Appendix 4).

The density of seedling in descending order was *Allophyllus abyssinicus (440.5 ha^{-1}), Bersama abyssinica (105 ha-^{1}), Maytenus arbutifolia (81ha-^{1}), Rubus apetalus (81ha-^{1}), Polyscias fulva (66 ha-^{1}),* and *Croton macrostachys (62 ha-^{1})* accounted about 59% of the total woody plants. Out of the 37.7% were not represented by their seedlings (Appendix 4).

4.3. Frequency

The frequency of woody species in this forest is given in Table 1 six woody species with the most frequently observed were individuals *Dombeya torrida, Allophylus abyssinicus, Croton macrostachys, Syzygium guineense, Podocarpus falcatus and Bersama abyssinica* belong to class C, while *Maytenus arbutifolia , Teclea nobilis, Rubus apetalus, Discopodium penninervium, Ekebergia capensis. Vebris dainellii, Dovyalis abyssinica, Millettia ferruginea* *and Maesa lanceolata* belong to class D. On the other hand, class E encompasses all the remaining species (Table1).

Frequency gives an approximate indication of the homogeneity of a stand. High values in higher frequency class and low values in lower frequency classes (Freq. classes E and D) indicate constant or similar species composition (IBC, 2003). High values in lower frequency classes and low values in higher classes; on the other hand, indicate a high degree of floristic heterogeneity. In the present study high values were obtained only in lower frequency classes (Table 1).Therefore, according to the above interpretation, it is possible to conclude that there exists a higher degree of floristic heterogeneity in Gonbiso natural forest because frequency distribution of this forest was dominated by only lower frequency classes (D and E) which account 90% of the total frequency, while only 10% belonged to higher frequency classes of C (Table 1).

Table 1: Frequency Classes of Woody Plant Species in Gonbiso Natural Forest

Botanical name	Total freq.	Percent Freq.	Relative freq.%	Class
Dombeya torrida.	*28*	*56*	*5.1*	*C*
Allophylus abyssinicus	26	52	4.76	C
Croton macrostachys	25	50	4.57	C
Syzygium guineense	22	44	4	C
Podocarpus falcatus	22	44	4	C
Bersama abyssinica	21	42	3.84	C
Maytenus arbutifolia	18	36	3.29	D
Teclea nobilis	18	36	3.2	D
Rubus apetalus	16	32	2.93	D
Discopodium penninervium	15	30	2.74	D
Ekebergia capensis	13	26	2.32	D
Vebris dainellii	12	24	2.19	D
Dovyalis abyssinica	12	24	2.19	D
Millettia ferruginea	11	22	2	D
Vernonia auriculifera	10	20	1.8	E
Schefflera volkensii	10	20	1.8	E
Canthium crassum	10	20	1.8	E
Vernonia amygdalina	10	20	1.8	E
Polyscias fulva	9	18	1.64	E
Deinbollia kilimandscharics	9	18	1.64	E
Vernonia leopoldii	9	18	1.64	E
Schefflera abyssinica	9	18	1.64	E
Hagenia abyssinica	8	16	1.46	E
Galineria saxifraga	8	16	1.46	E

Contd…

Cassipourea malosana	8	16	1.46	E
Justicia schimperiana	8	16	1.46	E
Ocimum graftissimum	8	16	1.46	E
Albizia abyssinicus	8	16	1.46	E
Rytigynia neglecta	7	14	1.28	E
Ehretia cymosa	7	14	1.28	E
Schrebera alata	7	14	1.28	E
Maesa lanceolata	7	14	1.28	E
Erythrina brucei	7	14	1.28	E
Apodytes dimidiata	7	14	1.28	E
Hypericum revolutum	7	14	1,28	E
Maytenus undata	7	14	1.28	E
Fagaropsis angolensis	6	12	1.09	E
Acanthus arborius	6	12	1.09	E
Nuxia congesta	6	12	1.09	E
Arundinaria alpine	6	12	1.09	E
Ricinus communis	6	12	1.09	E
Solanum incanum	6	12	1.09	E
Cordia africana	6	12	1.09	E
Celtis africana	6	12	1.09	E
Prunus africana	5	10	0.91	E
Rubus steudneri	5	10	0.91	E
Olea welwitschii	5	10	0.91	E
Diosporyus abyssinica	5	10	0.91	E
Euphorbia abyysinica	5	10	0.91	E
Phytolacca dodecandri	5	10	0.91	E
Carissa edulis	5	10	0.91	E
Phoenix reclinata	4	8	0.73	E
Pouteria adolfi -friederici	4	8	0.73	E
Rhus vulgaris	4	8	0.73	E
Juniperus procera	3	6	0.54	E
Ilex mitis	3	6	0.54	E
Rhus natalensis	3	6	0.54	E
Rhamnus staddo	3	6	0.54	E
Calpurnia aurea	3	6	0.54	E
Flacourtia indica	2	4	0.36	E
Total			100	

Key: C=41-60%; D=21-40%; and E=0-20%

4.4. Basal Area and Important Value Index

The total basal area of Gonbiso natural forest is about 59.85 m^2 ha-^{1}. *Allophyllus abyssinicus* was the dominant species in the forest compressing (19.4%) of the total basal area .Other dominant Species includes *Polyscias fulva (15.9%), Prunus africana (9.32%), and Syzygium guineense (6.5%), and Millettia ferruginea (5.78%), Apodytes dimidiata (4.42%).* These species covers 61.32% the total basal area. The species with the largest contribution in basal area can be considered the most important species in the forest. On the other hand the remaining woody species covers only 38.68% of the total basal area. Species with the highest basal area per hectare does not always have the highest density indicating the size differences between the species. (Appendix3).

When the basal area of this forest is compared with other related forests, it has higher basal area than Chilimo forest (27.3m^2 ha-^{1}) (Woldemariam *et al.* 2000): Menagesha forest (32.4 m^2) (Bekele 1993) but much smaller than Dodola forest (129m^2ha-^{1}) (Hundera *et al.,* 2007).

There is close relation ship between basal area and DBH value. This may be due to variation in the conservation of the forest, exposure to deforestation and geographical location of the forest.

The relative ecological significance or dominance of tree species in a forest ecosystem could best be unraveled from analysis of IVI values (Curtis and Meintosh1950 cited in Yineger *et al.,* 2008). In Gonbiso Natural forest about 35.90% of the importance value index was contributed by *Allophyllus abyssinicus, Croton macrostachyus, Schefflera abyssinica, Syzygium guineense, Millettia ferruginea* and *Dombeya torrida.* These species were abundant, frequent and dominant in the forest (Appendix 3). The remaining percentage (64.10%) was shared by among the rest species.

For the sake of setting priority using IVI analysis all woody species encountered in the forest were grouped in to five IVI classes based on their total IVI values (Table 2). As can be seen in Table 2, species which have lowest IVI value were grouped in to the fifth IVI class, where as those species with higher IVI value were put under the second IVI class because no species were found to be put in the first IVI class .Therefore, those species which were grouped in the fifth IVI class need high conservation effort, while those grouped in the second IVI class, need monitoring-management, and the others also need to receive conservation efforts accordingly

(IBC, 2003). However, in this forest, no species were found in the first IVI class. Thus, it can be concluded that species with higher IVI value in this forest were selectively removed.

Table 2: IVI Class and the Number of Species belonging to each Class

IVI Classes	Number of species	Sum of IVI	Percentage (%)
5 (<1)	7	3.56	1.21
4 (1-10)	48	174.09	59.5
3 (10.1-20)	6	87.73	30
2 (20.1-30)	1	27.02	9.3
1(>30)	0	0	0
Total	62	292.4	100

IVI indicates that the extent of dominance a species in the structure of a forest stand (Curtis and Mcintosh 1950 cited in Fisseha *et al.,* 2013). It is stated that species with the greatest importance value index are the leading dominance of the forest. Accordingly, the leading dominant species in Gonbiso natural forest are listed in the Table 3 below.

Table 3: List of Species under the Five Priority Classes

Priority Class				
5	4	3	2	1
Flacourtia indica	*Acanthus arborius*	*Schefflera abyssinica*	*Allophylus abyssinicus*	
Rhus natalensis	*Bersama abyssinica*	*Millettia ferruginea*		
Pouteria adolfi - friederici	*Maytenus arbutifolia*	*Dombeya torrida.*		
Phoenix reclinata	*Teclea nobilis*	*Croton macrostachys*		
Carissa edulis	*Rubus apetalus*	*Syzygium guineense*		
Olea europaea	*Discopodium penninervium*	*Prunus africana*		
Ficus vasta	*Ekebergia capensis*	*Podocarups falcatus*		
	Vebris dainellii			
	Dovyalis abyssinica			
	Vernonia auriculifera			

Contd..

	Canthium crassum				
	Vernonia amygdalina				
	Polyscias fulva				
	Deinbollia kilimandscharics				
	Vernonia leopoldii				
	Hagenia abyssinica				
	Galineria saxifraga				
	Cassipourea malosana				
	Justicia schimperiana				
	Ocimum graftissimum				
	Albizia abyssinicus				
	Rytigynia neglecta				
	Ehretia cymosa				
	Schrebera alata				
	Maesa lanceolata				
	Erythrina brucei				
	Apodytes dimidiata				
	Hypericum revolutum				
	Maytenus undata				
	Fagaropsis angolensis				
	Celtis africana				
	Nuxia congesta				

4.5. Vegetation community classification

The woody species identified from the study area were 62 but two species are not represented in their mature tree /shrub stage. So, only 60 woody species from 50 plots were used for vegetation community classification. Four vegetation community types (clusters) were identified (Table4). The vegetation analysis was derived from the abundance data of species. The cluster were significantly different ($p< 0.001$) using the Multiple Response permutation procedure (MRPP) test. The decision on the number of group was based on the MRPP technique and the ecological interpretation of the group.

The four clusters occupying different region of space as shown by strong chance–correlation within the group (A) and test statistics (T). The test statistics T-value for the four group were -19.72 ($P<0.001$) and statistics was 0.13. The test statistics T, described the separation between among groups, with more negative T value was the stronger separation. The agreement A describes within the groups homogeneity and falls between 0 and 1when all items within groups are identical A=1 and 0 when the group are heterogeneous (Table4).

Plant community refers to population of several plant species in a given area which are living together and interacting. Every plant community has its own characteristics and has usually one, two or three dominant species. Therefore; the four plant communities obtained in this analysis were named after one or two of the dominant indicator species. A species with significant indicator value at p*<0.05 was considered as an indicator species of the community for simple differentiation of the community type in the forest area. Community names were derived from two species that had the least p*value but the highest indicators values in the community (Table 4).

Table: 4 Indicator Values (% of perfect Indication, based on combining Relative Abundance and Relative Frequency) of each species for each of the four groups and the Monte Carlo test (P*) of the significance observed for each species. (Bold values indicate indicator species at P*<0.05).

Species name	Community				p*
	1	2	3	4	
Syzygium guineense (Willd.)	**37.6**	0	0	0	**0.112**
Ricinus communis L.	**20.7**	0	0	0.26	**0.2262**
Cassipourea malosana (Baker)	20.4	0.24	0	0	0.2739
Dombeya torrida (J.F. Gmel.)P.Bamps.	0.32	**63.2**	0	0	**0.0008**
Schefflera abyssinica (Hochst. ex A.Rich) H	0	**25.5**	0	0.20	**0.1544**
Ekebergia capensis sparrmam	.13	19	0	0	0.4425
Millettia ferruginea	0		**19.9**	**0**	**0.0002**
Cordia africana Lam.	0	0	24.9	0	0.1236
Maytenus arbutifolia (A.Rich) Wilezek	**0.1**		**23.4**	**0**	**0.0088**
Phytolacca dodecandri L.Herit	0	0	30.5	0.11	0.0614
Diosporyus abyssinica	0	0	27.7	0	0.1378
Albizia abyssinicus (Hochst)Radikofer	0.3	0	17.5	0	0.5377
Rubus steudneri Schweinf.	0	0	0.41	24.2	0.1438
Vernonia auriculifera Heirn.	0	0.14	0	48.9	0.0148
Solanum incanum L.	0.12	0	0	**9.22**	**0.0004**
Hagenia abyssinica (Bruce) J.F. Gmel.	0	0	0	**9.82**	**0.0016**
Erythrina brucei Schweinf.	0	0	0.13	43.7	0.0668
Arundinaria alpine K. Schun	0	0	0	47.5	0.0376
Justicia schimperiana	0	0.11	0	39.8	0.058
Polyscias fulva (Hiern) Harms	0	0	0	48.9	0.0148

With Test statistic T= (- 19.27) and chance- corrected with in group agreement A= 0.31

However, in the case of community one, because there were no species found in the forest having p*<0.05, species with relatively least p* value were considered as indicator species.

Results of the indicator species analysis for determining to which species were associated with the different group is shown in Table 4. Species are listed by group affinity in the ascending order of the probability (P) values. Value in bold refer to dominant species of the community. In all the communities, species with high indicator values are those that were easily observed in the field repeating themselves in association. Thus, the identified group more or less coincided with the natural association that while data collecting in the forest.

The four plant community types identified in this forest were *Syzygium guineense - Ricinus communis, Dombeya torrida - Schefflera abyssinica, Millettia ferruginea - Maytenus arbotifolia,* and *Solanum incanum* - *Hagenia abyssinica* (Table 4).

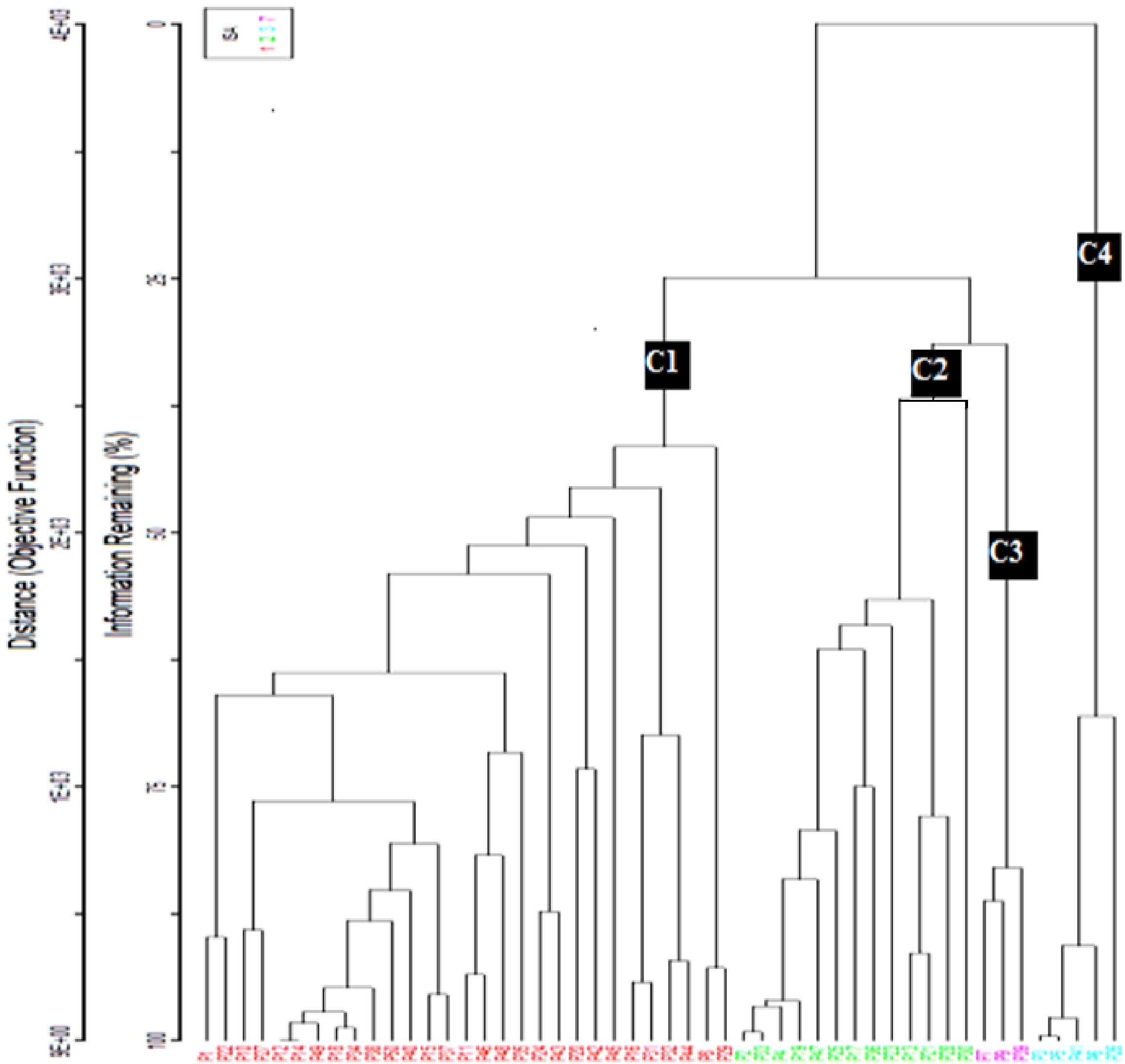


Figure 2: Dendrogram of the cluster analysis result of species abundance of 60 woody plant species found in 50 plots in GNF.

Where C1-Community1(1,22,10,27,12,14,49,18,34,38,50,40,15,37,11,46,48,35,24,43, 20, 42, 45, 16, 31,32, 44, 8 & 29).

C2-Community 2 (2, 33, 4, 19, 47, 25, 17, 36, 23, 13, 21, 28 & 30),

C3-Community 3 (7, 9 & 39),

C4-Community 4 (3, 5, 41, 6 and 26)

4.5.1. Description of the Plant Community

1 *Syzygium guineense - Ricinus communis* Community Type

The altitudinal range of this community type is between 2291and 2300 a.s.l and the mean slope of 22% .The community comprises 29 plots (1.16ha) and 16 woody species. Species in this community are *Syzygium guineense*, *Ricinus communis, Teclea nobilis, Phoenix reclinata, Galineria saxifrage, Carissa edulis*, *Dovyalis abyssinica, Vebris dainellii, Acanthus arborius, Cassipourea malosana* and *Olea welwitschii,* (Table4). This community was impacted by anthropogenic disturbance such as cutting of tress (30 stumps per hectare), and 35% and 37% of the plots are facing with medium and high grazing levels, respectively (fig 3a and 3b). The dominant indicator species of this community, *Syzygium guineense* which is highly distributed at altitudinal ranges from 2291to 2300 a.s.l.Similar result was reported by kelbessa *et a.,l* (2000).

2. *Dombeya torrida - Schefflera abyssinica* Community Type

The community type is located at an altitudinal range of 2308 - 2360 m a .s l. and the mean slope 21.5%. The community comprises 13 plots (0.52 ha) and 16 species. The common woody species in the community include *Dombeya torrida, Schefflera abyssinica, Ekebergia capensis, Cordia africana*, *Ilex mitis*, *Maytenus undata, Prunus africana, Juniperus procera* and *Rubus steudneri (*Table4). This community is facing with anthropogenic disturbance such as cutting of tree (80 stumps per hectare) (fig-6a), and 21% and 60% of the plot were with medium and high grazing level respectively (Fig-6b**).**

3. *Maytenus arbotifola –Millettia ferruginea* Community Type

The community occurs at an elevation between 2380-2422 m a .s. l. and 22.4% mean slope *Maytenus arbotifola*, *Millettia ferruginea, Hypericum revolutum, Nuxia congesta*, *Vernonia auriculifera, Discopodium penninervium, Schrebera alata*, *Albizia abyssinicus* and *Croton macrostachyus* are the dominant species in this community type (Table4). This community covers 3 plots (0.12ha) and 8 species. Its anthropogenic disturbance accounts (70 stumps per hectare) (Fig 6-a) and 60% and 16% of the plots are facing with medium and high grazing levels respectively.

4. *Solanum incanum- Hagenia abyssinica* Community Type

The community occurs at an elevation between 2310 -2380 m a. s. l and 23% mean slope. This community covers 5 plots (0.2 ha) 20 species. This community has anthropogenic disturbance such as cutting of tree (45 stumps per hectare) (fig3a). The plots are affected by medium and high grazing levels with 40% and 41% each (fig3b). The dominant species for this community were *Solanum incanum, Hagenia abyssinica, Allophylus abyssinicus, Celtis africana, Bersama abyssinica, Croton macrostachys, Polyscias fulva, Erythrina brucei, Maesa lanceolata, Rhus natalensis and Celtis africana (*Table 4).

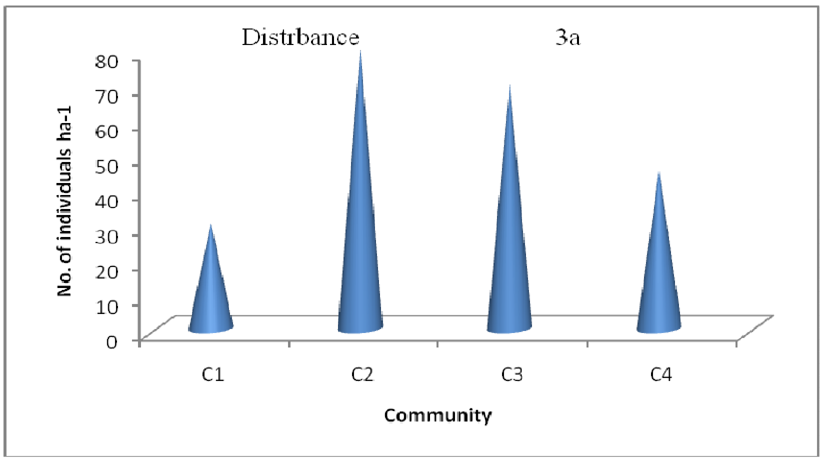
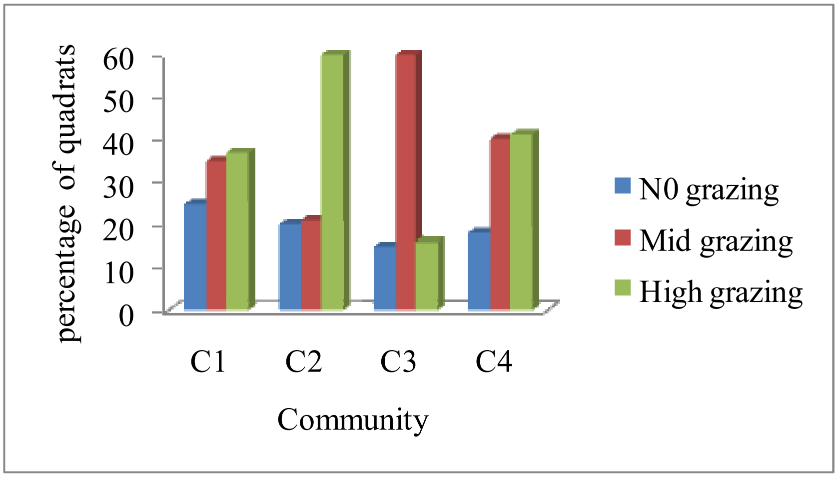


Fig 3a: Anthropogenic Disturbance in each Community

Key: C1=Community 1, C2=Community2, C3= Community3& C4=Community4



C1=Community 1, C2=Community2, C3= Community 3 and C4=Community 4

Fig 3b: Grazing Level

4.5.2. Species Richness, Species Evenness and Species Diversity of Plant Community Types

Species richness evenness and diversity of the plant communities of the forest are given in table 5 below

Table 5: Shannon- Weiner Diversity Index of Communities

Communities	Richness	Diversity	Evenness
Syzygium guineesse- Ricinus communis	16	0.181	0.065
Dombeya torrida- Schefflera abyssinica	16	0.165	0.059
Millettia ferruginea- Maytenus arbutifola	8	0.103	0.497
Solanum incanum- Hagenia abyssinica	20	0.141	0.471

Of the four community types, community *Syzygium guineense - Ricinus communitiess and Dombeya torrida - Schefflera abyssinica* have the same species richness. Whereas, community *Millettia ferruginea - Maytenus arbutifola* has the least specie richness and community *Solanum incanum-Hagenia abyssinica* scores the highest species richness (Table 5).

In terms of species diversity, *Syzygium guineense* - *Ricinus communis* has the highest species *diversity, while Millettia ferruginea* - *Maytenus arbutifola* has the least species diversity. *Dombeya torrida* - *Schefflera abyssinica* and *Solanum incanum - Hagenia abyssinica,* on the other hand, have intermediate species diversity (Table 5).*Millettia ferruginea* - *Maytenus arbutifola* has the highest specie evenness, followed by *Solanum incanum - Hagenia abyssinica,* while *Dombeya torrida* - *Schefflera abyssinica* and *Syzygium guineense* - *Ricinus communis* have the least species evenness.

There was no big difference in Shannon diversity index (0.103- 0.181), and evenness (0.059- 0.497) among the community. But there existed greater difference in species richness, which ranges from 8 to 20 (Table 5). The reason for similarity in diversity and evenness of these communities could be attributed to relatively simiral altitudinal range where as the difference in species richness may be due to domination of few species especially of community *Solanum incanum - Hagenia abyssinica.*Other environmental factor (soil and aspect) were not included in this study.

4.6. Vegetation Structure

Vegetation structure refers to the organization in space of the individuals that form a community by extension of a vegetation type or plant association. Growth forms, stratification, and coverage are the primary elements of structure.

4.6.1. Vertical Structure

The top height in this study area is 60 m. Accordingly, the scheme classes are ≥ 33.3m, >16.7m and < 16.7m for upper, middle and lower stories respectively.

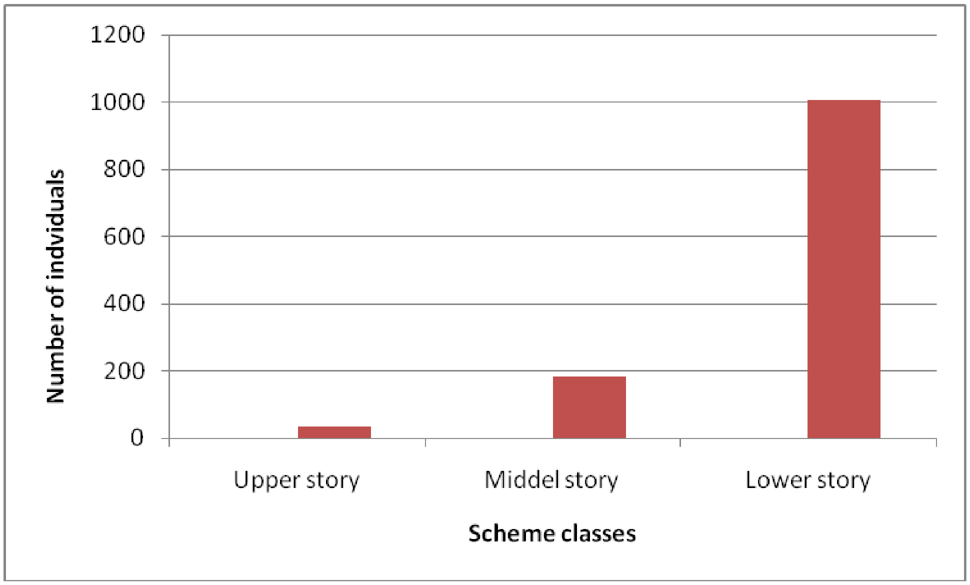


Figure: 4 Vertical Structures of Woody Plant Species in GNF

The emergent tree of GNF covers 12% of the woody plants registered, the ones being *Syzygium guineese, Allophyllus abssinicus Millettia feruginea, Croton macrostachyus, Prunus africana* are plants included in this story. The middle layer of the forest occupied 8% some of the plant include *Maesa lanceolata, Teclea nobilis,* and *Domboya torrida*. The lower story covers the highest density almost 80 % of the total woody plants which are largely dominated by shrub and small tree such as *Maytenus arbutifola, Vernonia amygdalina, Bersama abyssinica, Discopodium penninervum.* (figiure.4). In general no species were missed in the lower storey but there are many species, which couldn't attain the upper storey and the middle storey by their nature.

4.6.2. Diameter at Breast Height (DBH)

The DBH class distribution of all woody species is given in Figure 5 as the DBH class size increases the number of individuals decrease beginning from 390 individual's ha-^{1} (63.8%) in the 1th class down to 8 individuals' ha-^{1} (1.2%) in the 7th class and 5 individuals' ha-^{1}(0.81%) in the 8th class. This appears to be a regular distribution that resembles the inverted J-shaped distribution of individuals in the different DBH class. This indicates selective harvesting of individuals in the particular size classes. This is for timber, agricultural apparatus and firewood. If this selective cutting of certain DBH class continuous, the sustainability of the forest become under question. As can be seen in Figure 5, about 79.36% of the number of individuals was contributed by DBH class 1 and 2 indicating the predominance of small sized individuals in Gonbiso natural forest which contributed to small basal area.

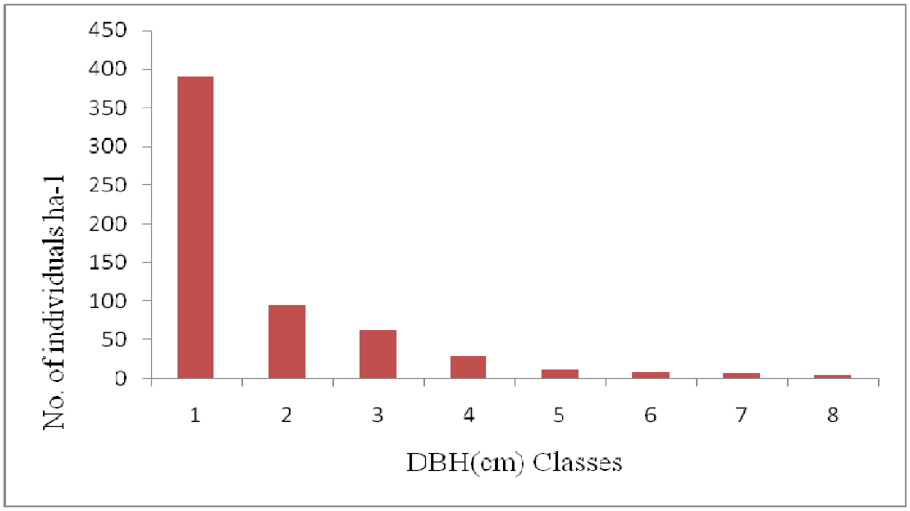


Figure 5: DBH Class versus Number of Individual in Gonbiso Natural Forest

Key: 1=2-10; 2=10.1-30; 3=30.1-50; 4=50.1-70; 5=70.1-90; 6=90.-110; 7=110.1-130 and 8 ≥ 130

As the DBH classes size increases, the number of individuals gradually decreases towards the higher DBH classes. Similar results were reported by Lulekal *et al*., (2008) and Senbeta (2006). Regarding the individual tree species of the study area, it was found that the dominant large-sized trees of the forest with DBH>130 cm were *Dombeya torrida, Syzygium guineese, Allophyllus abssinicus, Millettia feruginea, Croton macrostachyus*. The biggest diameter recorded in Gonbiso moist afromontane forest was *Schefflera abyssinica* (250cm), and *Syzygium guineese* (165cm.)

4.6.3. DBH Structure of Some of Woody Plant Species

Since the population structure of tree/shrubs has a significant implication on their management sustainable use and conservation, the population structure of woody species was analyzed and four representative population structure patterns are presented in Figure 6(a-d). Priority for selection of representative species is given to species with high value of IVI (Appendix3).

The analysis of density distribution among diameter class woody species in the forest resulted in different patterns (Figure 6a-d). High density is small diameter class indicate a good regeneration capacity, while under representation of these class indicate little regeneration capacity. An implication here is that the potential to replace such species will be very low on the mature individual have disappeared. This means that the species is endangered and needs conservation.

The first population pattern represented by *Allophyllus abyssinicus* (figure 6a) indicates low abundance in the 1st class and increase towards the 2nd class followed by dramatic decreases towards the 3rd class but increases towards the 4th class and again it continues to increases the abundance in the 5th class followed by gradual decrease towards 6th to 8th classes. This pattern indicates juvenile are not well represented and there is selective cutting for the purpose of fuel wood and charcoal as source of income. Hence, it calls for a need for conservation priority.

The second population pattern is represented by *Prunus africana* (figure 6b). This pattern indicates the presence of highest density in the lower DBH class with gradual decrease in density towards the bigger classes. It represents an inverted J –shaped curve and suggests good reproduction but bad recruitment (Shibru and Balcha, 2004). *Prunus africana* is large tree and therefore can have large DBH size but the abundance is very low or almost none starting from 2nd class. Here, it has bad regeneration status. Removal of mature tree increases the feature formation of seedling and sapling becomes endangered since the only source of seeds is mature tree. As a result, it needs sustainable conservation system.

The third population pattern is represented by *Croton macrostachyus* (figure 6c). This pattern shows low abundance in first DBH class, a gradual increase in the middle class followed by a decrease in abundance of individuals towards higher classes and totally missed from 6th - 8th classes. The same result was observed on *Domboya torrida*. This pattern indicates poor reproduction and a decline in number of big tree related to death or selective cutting of the big individuals by the local community near to the natural forest for their local apparatus use; hence, it calls a need for conservation priority such as *Croton macrostachyus, Domboya torrida and Podocarups falcatus* as they also showed this pattern.

The fourth population pattern is represented by *Millettia ferruginea* (figure 6d) which shows abnormal distribution pattern. *Millettia ferruginea* is totally absent in the first class with high abundance in the second class, decrease in classes 3, 4 and 5 with almost the same abundance, dramatically decrease in the 6th class followed by absence in the last two classes. This result concurs with the finding reported by Kelbessa and Soromessa (2008). The pattern indicates poor reproduction and selective removal of large sized individuals.

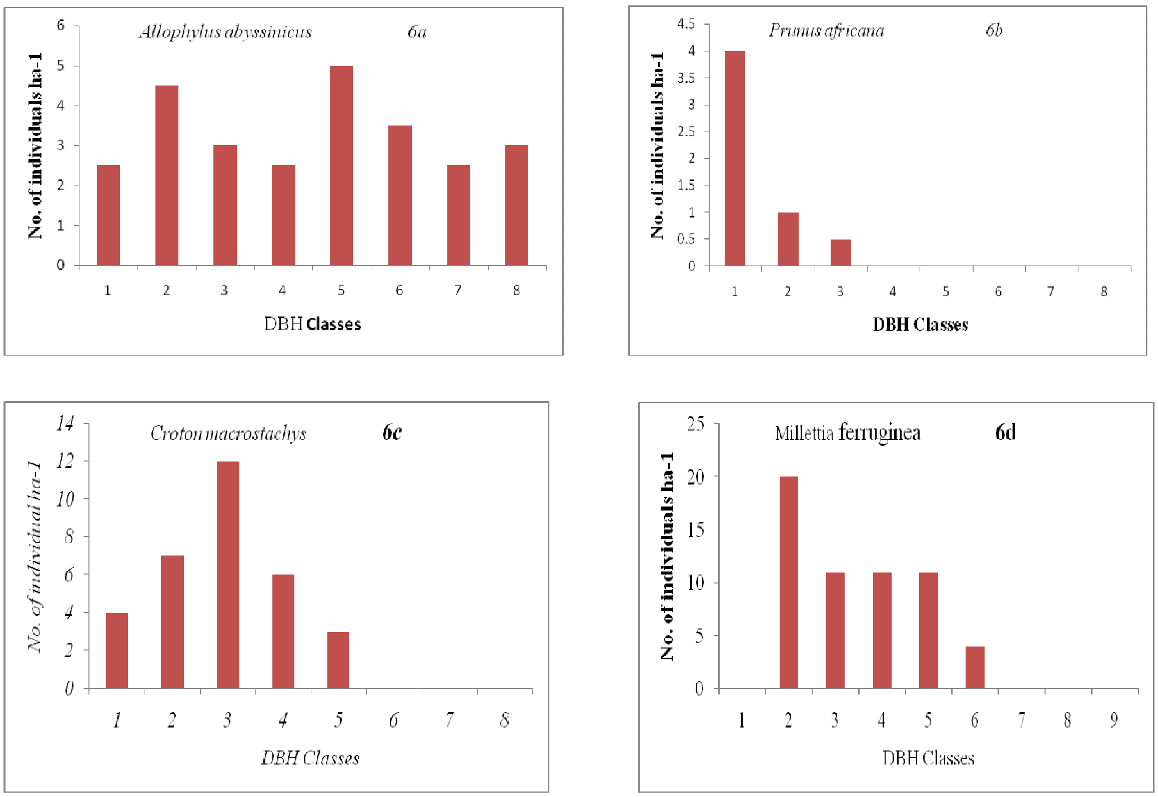


Fig 6a-d: Population Structure of Representative Woody Plant Species at Gonbiso Natural Forest by DBH class

Key1=2-10; 2=10.1-30; 3=30.1-50; 4=50.1-70; 5=70.1-90; 6=90.-110;7=110.1-130, and 8 ≥ 130 Height

4.6.4. Height

All woody plants greater than 3 meters were considered as mature tree/shrub where as individuals less than 3 meters were considered under sapling and seedling. The mature tree/shrub species in the study area were conveniently classified in to 10 height classes as presented in figure 10.

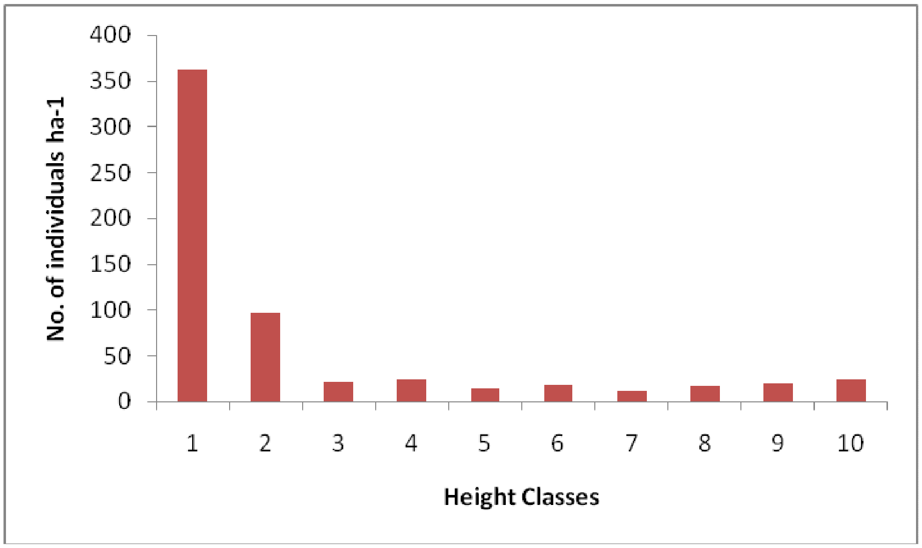


Figure: 7 Height Class Distributions of Woody Plants in GNF

Key1=3-6;2=6.1-9;3; 9,1-12;4=12,1-15;5=15.1-18;6=18.1-21;7=21.1-24;8=24.1-27;9=27.1-30;10≥ 30m

The result showed that the distribution of woody plants per hectare decreases with increasing height classes. The highest number of individuals was found to be 362 individuals ha-^{1} representing height class 1, which accounts 59.3% of the total classes. Woody plants under height class 2 and 3 together comprise 117 individuals ha-^{1} which makes up 19.2% of the total height class. Species that contribute most to the lower height classes (below 12m) in Gonibso natural forest are *Maytenus arbutifolia, Maesa lanceolata, Dovyalis abyssinica, Solanecio gigas, Hypericum revolutum, Discopodium penninervum, Vepris nobilis* and *Erica arborea*. These plants are shrubs or small trees in nature. Woody plants under height classes 4, 5, 6 and 7 together comprise only 10.9% of the total height classes in the forest.

Most plant species representing the medium height (between 12 & 24m) are *Croton macrostachyus, Teclea nobilis, Celtis africana, Bersama abyssinica,* and *Polyscias fulva.* From the study result, plant representing highest height class 8, 9 and 10 makes 10.6% of the total height classes. The upper canopy is dominated by *Prunus africana, Podocarpus falcatus,* and *Schefflera abyssinica* which are grown above all the canopy tree. This result shows us the forest have much number of small heighted woody plants than large heighted woody plant. So, strong commitment is needed for protection of large heighted woody plants from deforestation for their sustainability.

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4.7. Regeneration status of woody species in Gonbiso Natural Forest

Composition distribution and density of seedling and sapling would indicate the status of regeneration of the forest (Teketay, 1997). The sustainability of natural forests depends on the regeneration capacity of each species in the forest and sustainability of each species in turn depends on the sustainability of each individual tree/shrub. The regeneration condition or recruitment condition of woody species is one of the major factors that are useful to assess their conservation status (Bekele 1993).

From the investigation of seedling and sapling data a total of 36 species were represented in the seedling stage. All the regenerated species belonged to 34 genera and 21 families. This was only 58.1 % of the woody plant species in the forest (Table 6). The total seedling density was 1416 individuals' ha-^{1}. As compared to other forest in the same climatic conditions, the regeneration status of Gonbiso natural forest is slightly greater than that of Dodola forest, which had 31 species (Tenkir, 2006) but lower than that of Menagesha forest, which had 41 species (Teketay,1997).

The sapling stage was composed of 40 species representing 30 genera and 25 families. This equals 64.5 % of the woody plant species in the forest (Table 6). The total sapling density was 872.5 individuals ha-^{1} which summed up to give a total regeneration of 1745 individuals ha-^{1}. It was much less denser than Dodola forest which had 46879 ha^{-1} (Tenkir, 2006) and Menagesha forest 32,650 ha^{-1}(Tektay, 1997). This may be due to human intervention; especially, over grazing.

The ratio of woody species seedlings to mature individuals in the forest revealed that (2.3:1), seedling to sapling (1.6:1), and sapling to mature individuals in the forest (1.4:1). The result uncovered distribution of more seedling population than that of sapling and mature individuals.

Discopodium penninervum, Maytenus arbutifolia, *Bersama abyssinica, Rubus apetalus, Dovyalis abyssinica, Maytenus undata, Podocarpus falcatas* and *Erica arborea* were the most abundant species in the regeneration population which accounted 63% where as only 37% were contributed by the rest species. The pattern of life stage distribution of *Discopodium penninervum, Maytenus arbutifolia, Podocarpus falcatas* and *Erica arborea* species show higher number of individuals at the germinant stage and gradual decreases towards seedling sapling, and mature tree. According to Silvertown (1982) cited in Tenkir (2006) such distribution pattern commonly referred as J shaped, which has a good regeneration potential. This shows as the future status of the forest will be covered by few dominant species which leads to less diversification of the forest.

Some economic and ecological important species such as *Arundinaria alpine, Ilex mitis, Juniperus procera,* and *Prunus africana,* were absent in the regeneration strata (Table 6). This may be attributed to the fact that matured individuals of these species were harvested for house construction, timber production and for production of different household furniture. This may suggest that these species are either under threat of local extinction or may prefer coppices or sprout as the strategy of survival.

Analysis of regeneration status of all the woody species is presented in Table 6 following (Chauhan *et al.,* 2008). Of the 62 woody species in Gonbiso natural forest 19.4% showed good regeneration, 38.7 % fair, and 17.7% poor, while 22.6% lacked regeneration. The remaining 1.6% seem to be either reappearing in natural forest.

Table 6: Regeneration status of woody plants in GNF under three growth stages

S. No	Botanical name	Density per hectare			Regeneration status
		Tree/shrub	Sapling	Seedling	
1	*Dombeya torrida.*	43.5	0	0	None
2	*Allophylus abyssinicus*	26.5	12	40	Fair
3	*Croton macrostachys*	16	4.5	31	Fair
4	*Syzygium guineense*	26	8	40	Fair
5	*Podocarpus falcatus*	7.5	30	11	Poor
6	*Bersama abyssinica*	17.4	44.5	105	Good
7	*Maytenus arbutifolia*	22	122	62	Fair
8	*Teclea nobilis*	16	66	18	Fair
9	*Rubus apetalus*	21	26	81	Good
10	*Discopodium penninervium*	15	16	20	Good
11	*Ekebergia capensis*	5	6	13	Good
12	*Vebris dainellii*	7.5	32	27	Fair
13	*Dovyalis abyssinica*	7.5	16	22	Good
14	*Millettia ferruginea*	58.8	20	43	Fair
15	*Vernonia auriculifera*	20	20	62	Good
16	*Schefflera volkensii*	14	0	8	Fair
17	*Canthium crassum*	12.5	44	15	Fair
18	*Vernonia amygdalina*	10.5	10	19	Fair
19	*Polyscias fulva*	5	5	62	God
20	*Deinbollia kilimandscharics*	17	40	0	Poor
21	*Vernonia leopoldii*	15	24	21	Fair
22	*Schefflera abyssinica*	9.5	8	5	Fair
23	*Hagenia abyssinica*	7	0	1	Fair
24	*Galineria saxifrage*	6	12	14	Good
25	*Cassipourea malosana*	6.5	4	33	Fair
26	*Justicia schimperiana*	7.5	30	0	Poor
27	*Ocimum graftissimum*	6	0	0	None
28	*Albizia abyssinicus*	8	0	0	None
29	*Rytigynia neglecta*	6.5	0	4	Fair
30	*Ehretia cymosa*	5	0	0	None
31	*Schrebera alata*	5	2	6	Fair
32	*Maesa lanceolata*	4	15	0	Fair
33	*Erythrina brucei*	10.5	0	0	None
34	*Apodytes dimidiate*	6	20	0	Poor
35	*Hypericum revolutum*	10.5	0	0	None
36	*Maytenus undata*	16	43	83	Good
37	*Fagaropsis angolensis*	8.5	26	48	Good
38	*Acanthus arborius*	5	0	8	Fair

Cont….

39	*Celtis africana*	6	0	0	None
40	*Nuxia congesta*	7	0	0	None
41	*Arundinaria alpine*	4.5	20	4	Fair
42	*Ricinus communis*	7	0	0	None
43	*Solanum incanum*	15.5	22	0	Poor
44	*Cordia africana*	1.5	0	0	None
45	*Prunus africana*	5.5	12	37	Good
46	*Rubus steudneri*	3	24	0	Fair
47	*Olea welwitschii*	4.5	4	5	Good
48	*Diosporyus abyssinica*	7	0	1	Fair
49	*Euphorbia abyysinica*	7.5	2	12	Fair
50	*Phytolacca dodecandri*	2.5	24	16	Fair
51	*Carissa edulis*	2.5	0	0	None
52	*Phoenix reclinata*	2	0	2	Fair
53	*Pouteria adolfi -friederici*	2	16	0	Poor
54	*Rhus vulgaris*	3.5	0	0	None
55	*Juniperus procera*	4.5	4	0	Poor
56	*Ilex mitis*	4	30	0	Poor
57	*Rhus natalensis*	2	0	0	None
58	*Ficus vasta*	0	1	0	New
59	*Rhamnus staddo*	3	10	0	Poor
60	*Olea europaea*	0	0	2	New
61	*Calpurnia aurea*	1.5	0	0	Poor
62	*Flacourtia indica*	1	0	0	Poor
Total		610.5	872.5	1,416	

4.8. Regeneration status of some representative woody plant species of GNF

Selection of the representative woody plants species for this analysis was based on IVI (Table 5). Locally threatened and representation of the regeneration categories. Depending on the regeneration behaviors of all the woody species in the forest the following representative species are selected and discussed below under different categories

Prunus africana (figure 8a):- this pattern of distribution shows higher number of seedling and sapling than the mother plant and the number of sapling are better represented than the mature individuals of tree. The pattern has many individuals at seedling stage and decrease number of individuals successively at sapling and adult stages and exhibited typical inverted J-shape curve

Kelbessa and Soromessa (2008). Species with this pattern of regeneration behavior include *Bersama abyssinica, Dovalis abyssinica* and *Galineria saxifraga* this pattern have good regeneration potential.

Maesa lanceolata (figure. 8b):- this pattern consists of few mature individuals but no seedlings and sapling individuals which substitute the mother plant. Species with such type of pattern are no juvenile (Kelbessa and Soromessa, 2008).

*Olea europaea (*figure 8c):- this pattern of distribution has only few seedlings but there is no sapling as well as mature stage.

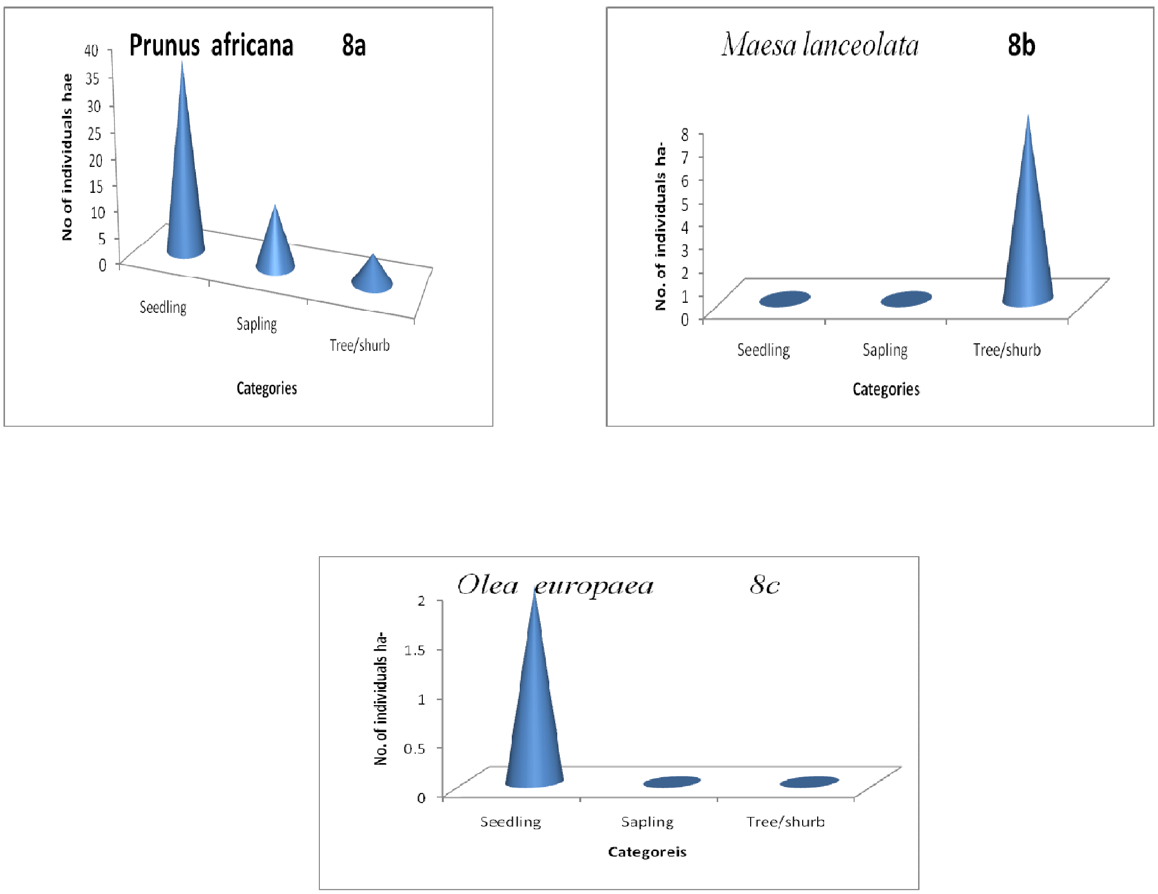

Fig.8a-c: Regeneration Status of Some Woody plants

4.9. Status of the forest: An implication for conservation

The density of mature tree/shrub, seedling and sapling in two blocks are 610.5, 872.5, 1416 individuals ha^{-1}, respectively. The dominant trees/shrubs of the area were *Croton macrostachyus,* *Millettia ferruginea,* and *Maytenus arbutifolia*. Anthropogenic disturbance such as agricultural expansion and grazing are the main threat for the forest.

Phytogeographic comparision of Gonbiso moist Afromontane forest showed that it is related more to the moist evergreen montane forest than Dry everegreen forest as it is characterized by dominant species of moist mountane forest.

4.9.1. Threats for Gonbiso Natural Forest

Anthropogenic disturbance are the main threat of Gonbiso natural forest. Agricultural and settlement expansion (figure. 9a) fire wood illegal cutting for utensils and timber (figure.9 b - f) cattle rearing with the forest and grazing (figure.9g) are the main threats. The result of this research shows 80 stumps ha^{-1} and 60% of the plots are suffering with grazing.

As the local people and nearby experts indicated the main reason for such types of disturbance to the forest is lower level of awareness on the part of local community and lower level of attention from the concerned bodies at different level. The increased demand for agricultural, land emanating from the very high human population growth, is posing a threat to Gonbiso forest. As a result, strong efforts are expected from the concerned bodies to create awareness among local community for the sustainable of the forest protection activities and maintain its biodiversity.

It was attempted to take some pictures from the different aspects of the forest so as to show its situation and the level of disturbance of the forest during the survey time. Some of them are given here under.

Fig.9a

Fig.9b

Fig.9c

Fig. 9d

Fig. 9e

Fig. 9f

Fig. 9g

Figure 9 a-g: Antrophogenic effects

CHAPTER FIVE

CONCULUSION AND RECOMMENDATION

5.1. Conclusions

Gonbiso natural forest is one of the few remnant moist Afromontane forest of Ethiopia with high species density which accounts 610.5, 872.5, 1416 individuals ha^{-1} of mature tree/ shrub, sapling and seedling, respectively that belonging to 62 species 55 genera and 40 families. The forest could be considered as one of the biodiversity conservation center for *Podocarpus falcatus, Maytenus arbutifolia, Croton macrostachyus, Millettia ferruginea, Erica arboria, Ilex mitis,* and *Galiniera saxifrage.* For Gonbiso natural forest the main conservation strategy should be in-situ conservation technique. Based on the IVI, *Hagenia abyssinica, Cordia africana, prunus africana, Syzygium guineense, Olea europaea,* and *Schefflera abyssinica* should be given a due conservation priority.

The vegetation was grouped into 4 plant community type each of which had varying degrees of species richness and evenness. Within this community there are some economically and ecologically important species which have bad population structure that show abnormal pattern with no or few individuals at lower size classes. These were *Juniperus procera*, Podocarpus falcatus, *Hagenia abyssinica* and *Allophylus abyssincus*. Therefore, it needs to develop and implement effective forest management activity in the area to facilitate healthy regeneration and eventually guarantee the sustainable use of these species. Gonibiso natural forest has been demarcated since 2011 as natural forest. However, currently the forest is exposed to high rate of destruction because of the frequent contact of the local people for fuel, fodder, construction, timber extraction and other forest products.

5.2. Recommendation

Based on the results obtained from the study, the following recommendations were forwarded as an implication for conservation and management options. These are:

- Participatory forest management programs should be introduced and implemented to create awareness and sense of ownership of the local people so that local communities take responsibility for the management and conservation of the forest and become beneficiaries of the economic payback derived from this activity;
- Further studies on the forest's regeneration status and soil characteristics should be carried out;
- Detailed ethnobotanical studies are also required to explore the wealth of indigenous knowledge on the diverse uses of plants and their implication in conservation.
- Tree planting by the local community has to be encouraged to reduce the pressure on the natural forests and to create buffer zones.

REFERENCES

Alelign, A., Teketay, D., Yemshaw, Y. & Sue Edwards, S. (2007). Diversity and status of regeneration of woody plants on the peninsula of Zegie, northwestern Ethiopia**.** *Tropical Ecoogyl.* **48**(1): 37-49, 2007 ISSN 0564-3295.

Bekele, A. T. (2007.) *Useful tree and shrubs of Ethiopia identification, propagation and management for 17 agro-climatic zone* RELMA in ICRAF project, Nairobi, Kenya.

Bekele, T. (1993). Vegetation Ecology of Renunant Afromontane Forests on the Central Plateau of Shewa, Ethiopia, PhD Dissertation, Uppsala University, Uppssala, Sewden

Bekele, T. (2011). Forest diversity in fragmented landscapes of northern Ethiopia and implications for conservation. PhD Dissertation.

Bore Forest and Wild Life District Office (2015). PFM Data. Unpublished.

Chauhan, D.S., Dhanai, C.S., Singh, B., Chauhan, S., Todaria, N.P.and Khalid, M.A. (2008) Regeneration and tree diversity in natural and planted forests in a Terai - Bhabhar forest in Katarniaghat *wildlife sanctuary, Indian Tropical Ecology.* ***49****: 53–67.*

Didita, M., Nemomissa, S. & Woldemariam, T. (2010). Floristicand structural analysis of the Woodlandvegetation around Dello Menna, Southeast Ethiopia. *Journal of Forestry Research.* **21:** 395-408.

EFAP (Ethiopian Forestry Action Program) (1994). Ethiopian Forestry Action Program (EFAP).
EFAP, Addis Ababa

EPA (1998). National Action program to Combat Desertification. Vol.1. Addis Ababa, Ethiopia.

Ezra, M. (2001). Ecological degradation, rural poverty, and migration in Ethiopia: A contextual analysis. Department of Health and Senior Services, New Jersey.

Feyera, A. (2010). Floristic Composition and Structure of Chato Natural Forest in Horo Guduru, Wollega Zone of Oromia Region, West Ethiopia Unpublished M.Sc. thesis, AAU

Fisaha, G., Hundera, K. and Dalle, G. (2013). Woody Pants Diversity, Structural Analysis and Regeneration Stasus of Wof- washa Natural Forest: North-east Ethiopia. John Wilely& Sons Ltd. *Africa Journalof Ecologyl*. **51**: 599-608.

Friis, I., Rasmussen, FN., Vollesen, K.(1982). *Studies in the flora and Vegetation of Southwest Ethiopia.* Denmark: Institute of Systematic Botany, University of Copenhagen, p. 67

Friis, I. (1992). *Forest and Forest Trees of Northeast Tropical Africa*: Their natural habitats and distribution pattern in Ethiopia, Djibouti and Somalia. *Kew. Bull. Additional Series***15**: 1-39

Friis, I., Demissew, S. and van Bruegel, P. (2010). *Atlas of the Potential Vegetation of Ethiopia.* The Royal Danish Academy of Science and letters, Denmark.

Gebrehiwot, M. (2003). Assessment of natural regeneration diversity and distribution of forests tree species. Unpublished M.sc.thesis, Enshede, Netherlands.

Geist, H.(2006) .*Our Earth's Changing Land:* An Encyclopedia of Land Us Land Cover Change. Greenwood Press. London.

.Gessesse, D. and istiansson, C. (2008). Forest decline and its causes in the south-central Rift Valley of Ethiopia: Human impact over a one hundred year perspective. *Ambio* **37**: 263-271.

Gessesse, B. (2010). The role of Geoinformation Technology for predicting and mapping of forest cover spatio-temporal variability: Dendi District Case Study, Ethiopia. *JSDA*. **12**: 1- 33

Harmer, R. (1994). Natural Regeneration of Broadleaved Tree in Britain; I. *Historical Aspects Forestry* **67**: 43-52.

Hundera, K. Bekele, T. and Kelbessa, E. (2007). Floristic and Phytogeographic Synopsis of a Dry Afromontane coniferous Forest in the Bale Mountains (Ethiopia): Implication to Biodiversity Conservation. SINET: *Ethiopia Journal of Science*. **30**(1): 1-12.

Hundera, K. and Deboch, B. (2008). Woody Species Composition and Structure of the Gura Farda Forest, Southwest Ethiopia. *Ethiopia Journal of Educ*ation and Science. **3**(2).

Hunt, C. (2002). Local and global benefits of subsidizing tropical forest conservation. *Environment and Development of Economics.* 7(2): 325-340.

IBC (2003). Forest Genetic Resource Conservation Project, IBCR- GTZ- Technical Report. Addis Ababa, Ethiopia

IBC (2007). Dry Evergreen Montane Forest and Evergreen Scrub Ecosystem, Addis Ababa, Ethiopia.

IBC (2010). Habitats of Ethiopia. Addis Ababa, Ethiopia

IUCN (2006). *Red List-Summary Statistics for Globally Threatened Species*. Gland, Switzerland and Cambridge, UK**1992**: 35−55.

Jones, K.B., Neale, A.C., Wade, T.G., Wickham, J.D., Cross, C.L., Edmonds, C.M., Loveland, T.R., Nash, M.S., Riitters, K.H. and Smith, E.R.(2001). *The consequences of landscape change on ecological resources*: An assessment of the United States mid-Atlantic region, 1973-1993. Ecosystem Health, 7, 229-242.

Kelbessa, E., Demissew, S.,Woldu, Z., and S (1992). *Some threatened Endemic Plants of Ethiopia.* In: Edwards S, Asfaw Z The Status of Some Plants in Parts of Tropical Africa, Botany 2000: NAPREC, Monograph Series No.2. Ethiopia: Addis Ababa University.

Kelbessa, E., Bekele, T., Gebrehiwot, A. and Hadera, G. (2000). Asocio-economic case study of the Bamboo sector in Ethiopia; An analysis of the production to consumption system Addis ababa, Ethiopia.

Kelbessa, E. and Soromessa, T. (2008). Interfaces of Regeneration, Structure, Diversity and Uses of Some Plant Species in Bonga Forest: A Reservoir for Wild Coffee Gene Pool. SINET: *Ethiopia Journal of Science.* **31**(2):121–134, ISSN: 0379–2897.

Kent, M. and Cooker, P. (1992). *Vegetation Description and Analysis*. A practical approach. John Wiley and Sons. New York, USA.

Kippie, T. (2002). Five thousand years of sustainability? A case study on Gedeo landuse (Southern Ethiopia). Dissertation, Wageningen Agricultural University, Wageningen, 296 p

Lemenih, M. & Teketay, D. (2006). Changes in soil seed bank composition and density following deforestation and subsequent cultivation of a tropical dry Afromontane forest in Ethiopia. *Ethiopia Journal of Science*. **12**: 63-93 **47**: 1-12.

Lulekal, E., Kelbessa, E., Bekele, T., Yineger, Y. (2008). Plant species composition and structure of the Mana Angetu moist montane forest, Southeastern Ethiopia. *Journal of East Africa National History*.**97**(2): 165-185.

Lisanework, N., Mesfin, T. (1989). An Ecological study of the vegetation of the Harenna forest, Bale, Ethiopia. *SINET: Ethiopia Journal of Science*. **12**: 63-93.

Logan, W.E. (1946). *An introduction to the forests of Central and Southern Ethiopia*. Imperial Forestry Institute Paper 24: 1-58.

Lovett, J.C., Rudd, S. and Frimodt-Muler, C. (2000). Patterns of plant diversity in Africa, South of the Sahara and their implication for conservation management. *Biodiversity conserve* **9**: 37-46.

McCune, B. and Mefford,M.J.(1999). PC-ORD. *Multivariate Analysis of Ecological Data V.0ersion* Version 5.0 MjM Soft ware, Gleneden Beach,Oregon, USA.

Moges, S. and Reddy, R. U. (2013). Farmers Perception on Deforestation in Ziway Dugda Woreda, Arsi Zone, Oromia Regional State of Ethiopia.*European Academic Research.* **1(9):** 2686-2701.

Mueller-Dombois D. and Ellenberg H. (1974). Aims and methods of vegetation ecology. John Wiley & Sons, Inc., New York.

NBSAP (2005). *National Biodiversity Strategy and Action Plan*, Addis Ababa, Ethiopia.

Nune, S.Kassie, M. and Mungatana, E. (2010). Forestry resource accounting: the experience of Ethiopia. CEEPA Discussion Paper No 47, Centre for Environmental Economics and Policy in Africa, University of Pretoria, South Africa.

Okoti, M., Ng'ethe, J. C., Ekaya, W. N., and Mbuvi, D. M.(2004). Land use, ecology, and socio-economic changes in a pastoral production system. *Journal of Human Ecology.* **16**(2).

Pappies, A. N., Armah, F.A., Quaye, E.C, Kwakye, P.K. and Buxton, G.N. (2010). Composition and stand structure of a tropical moist semi deciduous forest in Ghana. *Institute of Resarech Journal of Plant Science.* **1**: 095-106.

Peters, C.M. (1996). The Ecology and Management of Non-Timber Forest Rsources. World Bank Technical Paper 322, ISBN 0-8213- 3619- 3, Washington.

SCBD: Secretariat of the Convention on Biological Diversity (2001). The Value of Forest Ecosystems. Montreal, SCBD, 67p. (CBD Technical Series no. 4).

Senbeta, F. and Teketay, D. (2003). Diversity, community types and population structureof woody plants in Kimphee Forest, a virgin Nature Reserve in Southern Ethiopia. *Ethiopia Journal of Biological Science.***2(**2**):** 169-187.

Senbeta, F.(2006). *Biodiversity and Ecology of Afromontane rainforest with wild coffee Arabic L. Ppulation in Ethiopia*. Ecology and Development Series No.38. Center for Research, University of Bonn. Bonn Germany.

Shibru, S. and Balcha, G. (2004). Composition, Structure and regeneration status of woody species in Dindin Natural Forest, Southeast Ethiopia: An implication for conservation. *Ethiopia Journal of Biological Science.***13**: 15-35.

Soromessa, T., Tektay, D., Demissiew, S. (2004). Ecological study of the vegetation in Gamo gofa zone, Southern Ethiopia. *Tropical Ecollogy.***45** (2): 209-221

Steininger, M. K., Tucker, C. J., Ersts, P., Killeen, T. J., Villegas, Z., and Hecht, S. B.(2001). Clearance and fragmentation of tropical deciduous forest in the Tierras Bajas, Santa Cruz, Bolivia. *Conservation of Biology.* **15**: 856-866.

Teketay, D. (1997) Seedling populations and regeneration of woody species in dry afromontane forests of Ethiopia. *Forest Ecology Management.* **98**: 149–165.

Teketay. D.,Bekele, T. and Hasse, G. (2000). Forests and Forest genetic resources of Ethiopia. In**:** Ethiopia: A Biodiversity Challenge**,** pp 2-3. A paper presented to conference of Biological Society of Ethiopia, Addis Ababa, Ethiopia and the Linnean Society of London, UK.

Teketay, D. (2001). Deforestation, Wood Famine and Environmental Degradation in Ethiopia's Highland Ecosystems: Urgent Need for Action. *Northeast African Studies.* **8**: 53-76

Tenkir, E. (2006). Soil Seed Bank Study and Natural Regeneration Assessment of Woody Species in Dodola Dry Afromontane Forest: Bale Mountains. Unpublished M.Sc. thesis. Addis Ababa University, Ethiopia.

Tesfaye, G.,Teketay, D., Fetene, M.and Beck, E. (2010). Regeneration of seven indigenous tree species in a dry Afromontane forest, Southern Ethiopia. *Flora* **205**: 135-143.

Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C., Erasmus, B.F.N., de Siqueira, M.F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., van Jaarsveld, A.S., Midgley, G.F., Miles, L., Ortega-Huerta, M.A., Peterson, A.T., Phillips, O.L. & Williams, S.E.(2004). Extinction risk from climate change. *Nature* **427**: 145-148.

Van der Maarel E. (2005). *Vegetation ecology - an overview*. In: van der Maarel E. Vegetation ecology. Blackwell Publishing, Oxford, pp. 1-51.

Vivero, J.L., Kelbessa, E. and Demissew, S. (2005). *The Red List of Endemic Trees and Shrubs of Ethiopia and Eritrea*. Fauna and Flora International. Cambridge, U.K.

Vivero, J.L., Kelbessa, E. & Demissew, S. (2006). *Progress on the Red list of Plants of Ethiopia and Eritrea.* Conservation and Biogeography of Endemic Flowering Taxa (eds.). Kew, London.

Wana, D., Giriraj, A.& Carl, B. (2009) in prep, Land use change in the southwest Ethiopian highlands. *Journal of Mountain Research and Development.*

Willig, M.R., Kaufman, D.M. & Stevens, R.D.(2003). *Latitudinal gradients of biodiversity*: Pattern, process, scale, and synthesis. Annual Review of Ecology Evolution and Systematics **34**: 273-309.

Woldemichael, L. Bekele, T. and Nemomissa, S. (2010). Vegetation Composition in Hugumbirda Gratkhassu National Forest Priority Area, South *TigrayCNCS2*(2);27-48.

Woldemariam,T Teketay, T S. Edwards and M. Olsson. (2000.) Woody plant and avian species diversity in a dry Afromontane forest on the central plateau of Ethiopia: Biological indicators for conservation. Ethiopian *Journal of Natural Resources* 2*: 255-293.*

Woldemariam, T. (2003). Vegetation of the Yayu forest in SW Ethiopia: impacts of human use and implications for *in situ* conservation of wild *Coffea arabica* L. populations. Cuvillier Verlag, Göttingen.

Worku, A. (2009). Status of traditional agroforestry and its future potential development as buffer zone agrofoerstry for the natural forest conservation in Burkitu peasant association, Oromia, Ethiopia. MS.c Thesis. Hawassa University, Ethiopia.

Yineger, H., Kelbessa, E., Bekele, T. & Lulekal, E. (2008) Floristic composition and structure of the dry afromontane forest at Bale mountains national park, Ethiopia. SINET: *Ethiopia Journal of Biological Science.***31**: 103–120.

Yeshitela, K. and Bekele, T. (2002). Plant community analysis and ecology of Afromontane and transitional rainforest vegetation of southwestern Ethiopia. *Ethiopia Journal of Science*. **25(2)**: 155-175.

Zeleke, G. (2003). *Resource use and poverty in the Ethiopian highlands*: Nature conservation and Resource. Addis Ababa, Ethiopia.

Zerihun, W. Feoli, E., Lisanework, N. NL.(1989). Partitioning an elevation gradient of vegetation from southeastern Ethiopia by probabilistic methods. *Vegetatoion*. **81**: 189−198

Appendix 1: List of Woody Plant Species Collected from Gonbisoo Natural Forest (2015)

Item No	Scientfic name	Family	Local name (Afan Oromo)
1	*Acanthus arborius Forsk*	Acanthaceae	Sakorru
2	*Albizia abyssinicus (Hochst)Radikofer*	Mimosaceae	Garbe
3	*Allophylus abyssinicus (Hochst.)Radlk.*	Sapindaceae	Sarijii
4	*Apodytes dimidiata E.Mey.exBenth*	Icacinaceae	Mea
5	*Arundinaria alpina K. Schun*	Posaceae	Leemee
6	*Bersama abyssinica Fresen*	Melianthaceae	Tibro
7	*Calpurnia aurea (Ait.) Benth.*	Fabaceae	Cekataa
8	*Canthium crassum(Schweinf).Hiern*	Rubiaceae	Gallo
9	*Carissa edulis L.*	Apocynaceae	Hagamsa
10	*Cassipourea malosana (Baker)*	Rhizophoraceae	Xillloo
11	*Celtis africana Burm. f.*	Ulmaceae	Mataqooma
12	*Cordia africana Lam.*	Boraginaceae	Waddeessa
13	*Croton macrostachys Del.*	Euphorbiaceae	Mokonnisa
14	*Deinbollia kilimandscharics Taub*	Spindaceae	Gimboda
15	*Diosporyus abyssinica*	Ebenaceae	Lookoo
16	*Discopodium penninervium Hochst.*	Solanaceae	Maaraaroo
17	*Dombeya torrida (J.F. Gmel.)P.Bamps.*	Sterculiaceae	Danisaa

Cont…

18	*Dovyalis abyssinica (A.Rich)Warburg.*	Flacourtiaceae	Dugo
19	*Ehretia cymosa Thonn.*	Boraginaceae	Uragaa
20	*Ekebergia capensis sparrmam*	Meliaceae	Anonu
21	*Erythrina brucei Schweinf.*	Papilionaceae	Walena
22	*Euphorbia abyysinica Gmel*	Euphorbiaceae	Adaamii
23	*Fagaropsis angolensis (Engl.) Dale*	Rutaceae	Sisa
24	*Ficus vasta Forssk*	Moracea	Harbu
25	*Flacourtia indica(Brm.f.)merr*	Flacourtiaceae	Hudhaa
26	*Galineria saxifraga (Hochst.) Bridson*	Rubiaceae	Kudumii
27	*Hagenia abyssinica (Bruce) J.F. Gmel.*	Rosaceae	Heto
28	*Hypericum revolutum Vahl*	Hypericaceae	Edera
29	*Ilex mitis(L) Radik*	Aquifuliaceae	Miesa
30	*Juniperus procera Hochst. ex.. Arich*	Cupressaceae	Hindessa
31	*Justicia schimperiana (Hochst. Ex Nees) T. Anderson*	Acanthaceae	Dhumuugaa
32	*Maesa lanceolata Forsk.*	Myricaceae	Abaayii
33	*Maytenus arbutifolia (A.Rich) Wilezek*	Celasteraceae	Kombolcha
34	*Maytenus undata(Thunb) Blakelok*	Celasteraceae	Kombolcha
35	*Millettia ferruginea*	Fabaceae	Dadhatu
36	*Nuxia congesta R.Br.Ex Fresen*	Loganiaceae	Udessa

Contd…

37	*Ocimum graftissimum L*	Lamiaceae	Hancabbii
38	*Olea europaea Mill.*	Oleaceae	Ejersa
39	*Olea welwitschii (Knob.); Gilg. & Schellenb.*	Oleaceae	Gagamaa
40	*Phoenix reclinata Jacq.*	Arecaceae	Mexii
41	*Phytolacca dodecandri L.Herit*	Phytolaecaceae	Harenja
42	*Podocarpus falcatus (Thumnb.)Mirb.*	Podocarpaceae	Birbirsa
43	*Polyscias fulva (Hiern) Harms*	Arliaceae	Guduba
44	*Pouteria adolfi -friederici(Eng.) Bachni*	Spotaceae	Qareroo
45	*Prunus africana (Hook.f.) Kalkman*	Rosaceae	Sukee
46	*Rhamnus staddo A.Rich*	Rhamnaceae	Kadida
47	*Rhus natalensis Benth ex Krausa*	Anacardiaceae	Tatessa
48	*Rhus vulgaris Meikle*	Anacardiaceae	Dabobesa
49	*Ricinus communis L.*	Euphorbiaceae	Qoboo
50	*Rubus apetalus Poir*	Rosaceae	Goraa
51	*Rubus steudneri Schweinf.*	Rosaceae	Goraa injorii
52	*Rytigynia neglecta (Hiern.)Robyns*	Rubiaceae	Miqee
53	*Scheffera abyssinica (Hochst. ex A.Rich) Harms.*	Araliaceae	Getama
54	*Schefflera volkensii Harms.*	Araliaceae	Oroini
55	*Schrebera alata (Hochst) Welw*	Oleaceae	Dame

Contd…

56	*Solanum incanum L.*	Solanaceae	hiddii
57	*Syzygium guineense (Willd.)*	Myrtaceae	Badeessaa
58	*Teclea nobilis Del.*	Rutaceae	Hadheessaa
59	*Vebris dainellii(pichi.serm)*	Rutaceae	Arabe
60	*Vernonia amygdalina L.*	Asteraceae	Ebicha
61	*Vernonia auriculifera Heirn*	Asteraceae	Reejii
62	*Vernonia leopoldii (sch.B.P)*	Asteraecae	Soyoama

Appendix 2: Shannon Species Diversity Index in Decending order

S. No	Botanical name	Abundance	pi	ln pi	pilnpi
1	*Millettia ferruginea .*	117	0.096	-2.343	-0.225
2	*Dombeya torrida.*	87	0.071	-2.65	-0.187
3	*Croton macrostachys*	64	0.052	-2.95	-0.153
4	*Allophylus abyssinicus*	53	0.043	-3.146	-0.135
5	*Syzygium guineense*	52	0.042	-3.17	-0.133
6	*Maytenus arbutifolia*	44	0.036	-3.324	-0.12
7	*Rubus apetalus*	42	0.034	-3.381	-0.112
8	*Bersama abyssinica*	35	0.028	-3.575	-0.1
9	*Teclea nobilis*	32	0.026	-3.649	-0.095
10	*Maytenus undata*	32	0.026	-3.649	-0.095
11	*Solanum incanum*	31	0.025	-3.688	-0.092
12	*Vernonia leopoldii*	30	0.024	-3.729	-0.09
13	*Discopodium penninervium*	30	0.024	-3.729	-0.09
14	*Canthium crassum*	25	0.02	-3.912	-0.078
15	*Vernonia amygdalina*	21	0.017	-4.074	-0.069
16	*Erythrina brucei*	21	0.017	-4.074	-0.069
17	*Hypericum revolutum*	21	0.017	-4.074	-0.069
18	*Ekebergia capensis*	20	0.016	-4.135	-0.066
19	*Vernonia auriculifera*	20	0.016	-4.135	-0.066
20	*Polyscias fulva*	20	0.016	-4.135	-0.066
21	*Schefflera abyssinica*	19	0.015	-4.199	-0.063
22	*Deinbollia kilimandscharics*	17	0.014	-4.342	-0.056
23	*Fagaropsis angolensis*	17	0.014	-4.342	-0.056
24	*Albizia abyssinicus*	16	0.013	-4.342	-0.056
25	*Vebris dainellii*	15	0.012	-4.423	-0.053
26	*Dovyalis abyssinica*	15	0.012	-4.423	-0.053
27	*Euphorbia abyysinica*	15	0.012	-4.423	-0.053

Contd….

28	*Podocarpus falcatus*	15	0.012	-4.423	-0.053
29	*Justicia schimperiana*	*15*	*0.012*	*-4.423*	*-0.053*
30	*Schefflera volkensii*	14	0.011	-4.509	-0.05
31	*Hagenia abyssinica*	14	0.011	-4.509	-0.05
32	*Nuxia congesta*	14	0.011	-4.509	-0.05
33	*Ricinus communis*	14	0.011	-4.509	-0.05
34	*Diosporyus abyssinica*	14	0.011	-4.509	-0.05
35	*Cassipourea malosana*	13	0.01	-4.606	-0.046
36	*Rytigynia neglecta*	13	0.01	-4.606	-0.046
37	*Ocimum graftissimum*	12	0.009	-4.71	-0.042
38	*Galineria saxifraga*	12	0.009	-4.71	-0.042
39	*Celtis africana*	12	0.009	-4.710.	-0.042
40	*Apodytes dimidiata*	12	0.009	-4.71	-0.042
41	*Prunus africana*	11	0.009	-4.71	-0.042
42	*Acanthus arborius*	10	0.008	-4.833	-0.039
43	*Schrebera alata*	10	0.008	-4.833	-0.039
44	*Ehretia cymosa*	10	0.008	-4.833	-0.039
45	*Olea welwitschii*	9	0.007	-4.961	-0.035
46	*Arundinaria alpine*	9	0.007	-4.961	-0.035
47	*Juniperus procera*	9	0.007	-4.961	-0.035
48	*Rubus steudneri*	9	0.007	-4.961	-0.035
49	*Maesa lanceolata*	8	0.006	-5.116	-0.031
50	*Ilex mitis*	8	0.006	-5.116	-0.031
51	*Rhus vulgaris*	7	0.005	-5.298	-0.026
52	*Rhamnus staddo*	6	0.004	-5.521	-0.023
53	*Phytolacca dodecandri*	5	0.004	-5.521	-0.023
54	*Carissa edulis*	5	0.004	-5.521	-0.023
55	*Phoenix reclinata*	4	0.003	-5.809	-0.017
56	*Pouteria adolfi -friederici*	*4*	*0.003*	*-5.809*	*-0.017*

Contd….

57	*Rhus natalensis*	4	0.003	-5.809	-0.017
58	*Calpurnia aurea*	3	0.002	-6.214	-0.012
59	*Cordia africana*	3	0.002	-6.214	-0.012
60	*Flacourtia indica*	2	0.001	-6.907	0.006
61	*Ficus vast*	0	0	0	0
62	*Olea europaea*	0	0	0	0
	Total	1221	1.497	-260.516	-3.653
			Diversity(H')	3.65	
			Evenness(J)	0.88	

Appendix 3: Woody plant species with frequency, relative frequency, density, relative density, basal area and relative dominance in descending order IVI.

+	Botanical name	Total freq.	Rel freq(%)	Density	Rel. density (%)	Basal area	Rel.Dominance (%)	IVI
1	*Dombeya torrida.*	28	5.1	87	7.12	3.152	2.63	14.85
2	*Allophylus abyssinicus*	26	4.72	53	4.34	21.5	17.96	27.02
3	*Croton macrostachys*	25	4.54	64	5.24	4.52	3.75	13.53
4	*Syzygium guineense*	22	3.99	52	4.25	7.189	6	14.2
5	*Podocarpus falcatus*	22	3.99	15	1.23	4.7693	3.98	9.2
6	*Bersama abyssinica*	21	3.81	35	2.86	2.941	2.45	9.12
7	*Maytenus arbutifolia*	18	3.26	44	3.6	2.89	2.41	9.27
8	*Teclea nobilis*	18	3.26	32	2.62	0.2467	0.2	6.08
9	*Rubus apetalus*	16	2.93	42	3.45	0.27	0.22	6.6
10	*Discopodium penninervium*	15	2.74	30	2.45	0.022	0.01	5.2
11	*Ekebergia capensis*	13	2.35	20	1.64	4.046	3.68	7.67
12	*Vebris dainellii*	12	2.17	15	1.23	2.109	1.76	5.16
13	*Dovyalis abyssinica*	12	2.17	15	1.23	0.018	0.015	3.42
14	*Millettia ferruginea*	11	1.99	117	9.58	6.382	5.33	16.9
15	*Vernonia auriculifera*	10	1.8	20	1.63	0.024	0.02	3.45
16	*Schefflera volkensii*	10	1.8	14	1.15	1.02	0.85	4.94
17	*Canthium crassum*	10	1.8	25	2.04	0.204	0.17	6
18	*Vernonia amygdalina*	10	1.8	21	1.70	0.151	0.12	3.62
19	*Polyscias fulva*	9	1.64	20	1.64	0.07	0.05	3.33
20	*Deinbollia kilimandscharics*	9	1.64	17	1.40	0.029	0.02	3.05
21	*Vernonia leopoldii*	9	1.64	30	2.5	2.941	2.45	6.54
22	*Schefflera abyssinica*	9	1.64	19	1.6	17.56	14.66	17.85

Cont…

23	*Hagenia abyssinica*	8	1.46	14	1.15	0.372	0.31	2.92
24	*Galineria saxifraga*	8	1.46	12	0.98	0.0241	0.02	2.46
25	*Cassipourea malosana*	8	1.46	13	1.06	2.92	2.43	4.95
26	*Justicia schimperiana*	8	1.46	15	1.23	0.008	0.006	2.69
27	*Ocimum graftissimum*	8	1.46	12	0.98	0.015	0.81	3.19
28	*Albizia abyssinicus*	8	1.46	16	1.31	0.253	0.21	2.98
29	*Rytigynia neglecta*	7	1.28	13	1.06	0.026	0.02	2.36
30	*Ehretia cymosa*	7	1.28	10	0.82	0.173	0.144	2.24
31	*Schrebera alata*	7	1.28	10	0.82	0.017	0.01	2.11
32	*Maesa lanceolata*	7	1.28	8	0.65	0.061	0.05	1.98
33	*Erythrina brucei*	7	1.28	21	1.72	2.447	2.04	4.3
34	*Apodytes dimidiata*	7	1.28	12	0.98	4.872	4.07	6.33
35	*Hypericum revolutum*	7	1.28	21	1.72	0.021	0.021	3.02
36	*Maytenus undata*	7	1.28	32	2.62	0.036	0.03	3.93
37	*Fagaropsis angolensis*	6	1.09	17	1.39	0.055	0.04	2.52
38	*Acanthus arborius*	6	1.09	10	0.82	0.066	0.05	1.96
39	*Celtis africana*	6	1.09	12	0.98	1.958	1.63	3.71
40	*Nuxia congesta*	6	1.09	14	1.14	2.811	2.34	4.57
41	*Arundinaria alpine*	6	1.09	9	0.74	0.01	0.008	1.83
42	*Ricinus communis*	6	1.09	14	1.15	4.872	4.07	6.31
43	*Solanum incanum*	6	1.09	31	2.53	0.044	0.036	3.65
44	*Cordia africana*	6	1.09	3	0.24	0.009	0.007	1.34
45	*Prunus africana*	5	0.91	11	0.9	10.274	8.58	10.39
46	*Rubus steudneri*	5	0.91	9	0.74	0.006	0.005	1.65
47	*Olea welwitschii*	5	0.91	9	0.73	2.705	2.25	3.89
48	*Diosporyus abyssinica*	5	0.91	14	1.14	0.008	0.006	2.06
49	*Euphorbia abyysinica*	5	0.91	15	1.23	0.1075	0.08	1.4
50	*Phytolacca dodecandri*	5	0.91	5	0.40	0.007	0.005	1.32
51	*Carissa edulis*	5	0.91	5	0.40	0.004	0.003	0.49

Contd...

52	*Phoenix reclinata*	4	0.73	4	0.33	0.003	0.002	0.405
53	*Pouteria adolfi - friederici*	4	0.73	4	0.33	0.003	0.002	0.405
54	*Rhus vulgaris*	4	0.73	7	0.57	0.009	0.007	1.31
55	*Juniperus procera*	3	0.54	9	0.74	0.488	0.407	1.69
56	*Ilex mitis*	3	0.54	8	0.65	0.007	0.005	1.195
57	*Rhus natalensis*	3	0.54	4	0.33	0.004	0.003	0.873
58	*Ficus sur*	0	0	0	0	0	0	0
59	*Rhamnus staddo*	3	0.54	6	0.49	0.006	0.005	1.035
60	*Olea europaea*	0	0	0	0	0	0	0
61	*Calpurnia aurea*	3	0.54	3	0.24	0.001	0.008	0.785
62	*Flacourtia indica*	2	0.36	2	0.16	0.001	0.08	0. 6
Total		551	100	1221	**100**	**119.70362** **59.85m^2**	**100**	292

Appendix 4: Density of Woody Plants in Three Life Stages of GNF

	Botanical name	Tree/shurb	Spling	Seedling	
1	*Dombeya torrida.*	87	0	0	
2	*Allophylus abyssinicus*	53	24	80	
3	*Croton macrostachys*	64	18	124	
4	*Syzygium guineense*	52	16	80	
5	*Podocarpus falcatus*	15	60	22	
6	*Bersama abyssinica*	35	89	210	
7	*Maytenus arbutifolia*	44	244	124	
8	*Teclea nobilis*	32	132	36	
9	*Rubus apetalus*	42	52	162	
10	*Discopodium penninervium*	30	32	40	
11	*Ekebergia capensis*	20	12	26	
12	*Vebris dainellii*	15	64	54	
13	*Dovyalis abyssinica*	*15*	*32*	*42*	
14	*Millettia ferruginea*	117	40	86	
15	*Vernonia auriculifera*	20	20	62	
16	*Schefflera volkensii*	14	0	8	
17	*Canthium crassum*	25	88	30	
18	*Vernonia amygdalina*	21	20	38	
19	*Polyscias fulva*	20	20	132	
20	*Deinbollia kilimandscharics*	17	40	0	
21	*Vernonia leopoldii*	30	48	42	
22	*Schefflera abyssinica*	19	16	10	
23	*Hagenia abyssinica*	14	0	2	
24	*Galineria saxifraga*	12	24	28	
25	*Cassipourea malosana*	13	8	66	

Cntd…

26	*Justicia schimperiana*	15	60	0	
27	*Ocimum graftissimum*	12	0	0	
28	*Albizia abyssinicus*	16	0	0	
29	*Rytigynia neglecta*	13	0	4	
30	*Ehretia cymosa*	10	0	0	
31	*Schrebera alata*	10	4	12	
32	*Maesa lanceolata*	8	60	0	
33	*Erythrina brucei*	21	0	0	
34	*Apodytes dimidiata*	12	40	0	
35	*Hypericum revolutum*	21	0	0	
36	*Maytenus undata*	32	86	166	
37	*Fagaropsis angolensis*	17	52	96	
38	*Acanthus arborius*	10	0	16	
39	*Celtis africana*	12	0	0	
40	*Nuxia congesta*	14	0	0	
41	*Arundinaria alpine*	9	40	8	
42	*Ricinus communis*	14	0	0	
43	*Solanum incanum*	31	44	0	
44	*Cordia africana*	3	0	0	
45	*Prunus africana*	11	24	74	
46	*Rubus steudneri*	9	48	0	
47	*Olea welwitschii*	9	8	10	
48	*Diosporyus abyssinica*	14	0	2	
49	*Euphorbia abyysinica*	15	4	24	
50	*Phytolacca dodecandri*	5	48	32	
51	*Carissa edulis*	5	0	0	
52	*Phoenix reclinata*	4	0	4	
53	*Pouteria adolfi -friederici*	4	32	0	

Contd…

54	*Rhus vulgaris*	7	0	0	
55	*Juniperus procera*	9	8	0	
56	*Ilex mitis*	8	60	0	
57	*Rhus natalensis*	4	0	0	
58	*Ficus sur*	0	2	0	
59	*Rhamnus staddo*	6	20	0	
60	*Olea europaea*	0	0	2	
61	*Calpurnia aurea*	3	0	0	
62	*Flacourtia indica*	2	0	0	
	Total	1221	1745	2832	

Appendix 5: Location of quadrats in relation to altitude, latitude, aspect and bearing

Transect	Quadrat	Altitude in m	Latitude-N	Longitude-E	Aspect	Bearing
Block 1	1	2380	0474000	0700500	West	270^0
	2	2379	0474100	0700500		
	3	2385	0474200	0700500		
	4	2390	0474300	0700500		
	5	2315	0474400	0700500		
	6	2401	0474500	0700500		
	7	2345	0474600	0700500		
Block 1	1	2390	0475000	0700000	Southwest	225^0
	2	2360	0475100	0700000		
	3	2369	0475200	0700000		
	4	2353	0475300	0700000		
	5	2354	0475400	0700000		
	6	2368	0475500	0700000		
Block 1	1	2384	0475500	0699500	South east	135^0
	2	2422	0475600	0699500		
	3	2319	0475700	0699500		
	4	2310	0475800	0699500		
	5	2320	0475900	0699500		
	6	2356	0476000	0699500		
Block 1	1	2353	475600	700500	East	90^0
	2	2378	475700	700500		
	3	2352	475800	700500		
	4	2380	475900	700500		
	5	2391	476000	700500		

	Contd…					
	6	2410	476100	700500		
Block 1	1	2315	474500	701000	North	360^0
	2	2354	474600	701000		
	3	2374	474700	701000		
	4	2380	474800	699500		
Block 2	1	2351	474900	699500	South	180^0
	2	2358	475000	699500		
	3	2360	476000	698500		
	4	2442	476100	698500		
	5	2370	476200	698500		
	6	2369	476300	698500		
	7	2367	476400	698500		
Block 2	1	2324	476500	698500	Northwest	315^0
	2	2291	475600	699500		
	3	2300	475700	699500		
	4	2391	475800	699500		
	5	2311	475900	699500		
	6	2308	476000	699500		
	7	2350	476100	699500		
Block 2	1	2340	476200	699500	Northeast	45^0
	2	2360	476300	699500		
	3	2380	476400	699500		
	4	2395	476500	699500		
	5	2405	476600	699500		
	6	2385	476700	699500		
	7	2395	476800	699500		