ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF BIOLGY

Floristic Composition and Structural Analysis of Komto Afromontane Rainforest, East Wollega Zone of Oromia Region, West Ethiopia

By Fekadu Gurmessa

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A Thesis presented to the School of Graduate Programme of Addis Ababa University in a partial fulfillment of the Degree of Masters of Science in Biology (Botanical Science stream)

By Fekadu Gurmessa

CONTENTS **PAGE**

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ACRONYMS

BA	Basal Area
CR	Critically endangered
DBH	Diameter at Breast Height
EFAP	Ethiopian Forestry Action Plan
EN	Endangered
EPA	Environmental Protection Authority
ETH	the National Herbaium
FAO	Food and Agriculture Organization
FEE	Flora of Ethiopia and Eritrea
GPS	Geograpical Position System
IBC	Institute of Bidiversity Conservation
IUCN	Intenational Union for Conservation of Nature and Natural Resources
IUFRO	International Union for Forestry Research Organizations
IVI	Importance Value Index
LC	Least concern
ln	Natural logarithm
MOA	Ministry of Agriculture
MRPP	Multi-Response Pemutation Procedure
NBSAP	National Biodiversity Strategy and Action Plan
NFPA	National Forest Priority Area
NMSA	National Meteorological Service Agency
NT	Near threatened
PCC	Population Census Commission
RD	Relative Density

RDO	Relative Dominance
RED	Relative Euclidean Distance
RF	Relative Frequency
TWINSPAN	Two Way Indicator Species Analysis
USAID	United States of America International Development
VU	Vulnerable
WBISPP	Woody Biomass Inventory and Strategic Planning Project
WDARDO	Wayu-Tuka District Agriculture and Rural Development Office
WG	Wollega floristic region
WRI	World Resource Institute

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ABSTRACT

This study was conducted on Komto Forest in East Wollega Zone, Oromia National Regional State, west Ethiopia with the objective of determining the floristic composition, vegetation structure, community type and regeneration status for some tree species in the forest. Systematic sampling method was used to collect vegetation data. Accordingly, 53 quadrats each with 400 m^2 (20 m X 20 m) for woody species and subplots of 1 m X 1 m within the main plots for herbaceous plants were laid along line transects radiating from the peak of Komto Mountain in 8 directions. All plots (quadrats) were laid at a distance of 200 m along the transect lines. For seedlings, the main quadrats were divided into subplots of 10 m X 10 m (100 m^2) to make seedling counting easier. In each of these quadrats, all vascular plant species were collected and brought to ETH for identification. In addition, vegetation parameters such as DBH, height and seedling and sapling density of woody species including location and altitude of each quadrat were recorded. Vegetation classification was performed using PC-ORD software packages. Sorensens's similarity coefficient and Shannon-Wiener diversity index were also used to detect similarities among communities and to compute species richness and evenness between the plant communities respectively. A total of 180 species in 151 genera and 66 families were identified from the forest out of which 31 were new records from Wollega (WG) floristic region for the flora of Ethiopia and Eritrea. Fabaceae and Asteraceae are the dominant familes in terms of species richness. Furthermore, 18 endemic species some of which are under the Red Data List of IUCN were also identified. In this study, four plant communities were identified and described. Structural analysis of some selected tree species revealed different population pattern. Generally, the forest was dominated by small sized trees and shrubs indicating that it is in the stage of secondary regeneration. Phytogeographical comparison of Komto Forest revealed the highest similarity with moist montane forests which asserts that Komto Forest is one of the moist montane Forests in Ethiopia. Studies on the structure and regeneration of the forest indicated that there are species that require urgent conservation measures. Therefore, based on the results of this study, detailed ecological studies in relation to various environmental factors such as soil type and properties, ethnobotanical studies to explore indigenous knowledge on the diverse uses of plants, and sound management and monitoring as well as maintenance of biodiversity that promote sustainable use of the forest and its products are recommended.

Key Words/Phrases: East Wollega Zone, Komto Forest, Plant community, Species richness, Regeneration, and Sustainable use of forest and its products

1. INTRODUCTION

1.1 Background of the Study

The vegetation cover of a given area has a definite structure and composition, which is developed because of the long term interaction between biotic and abiotic factors. The pattern of distribution and vertical stratification of vegetation fluctuate due to different climatic zones, soil types, latitude and topography of the area. These in turn influence the distribution and type of plants and animals in the forest (Mueller-Dombois and Ellenberg, 1974).

Ethiopia is found in the horn of Africa and located between $3^0 24^'$ and $14^0 53^'$ North and $32^0 42^'$ and $48^0 12^'$ East with a total area of 1.12 million km^2 (MoA, 2000). The Altitudinal range of the country varies from 110 m below sea level at Kobar sink in Afar to 4620 m a.s.l, the highest peak of Ras Dejen (IBC, 2008). The highland plateau of Ethiopia with an altitude of above 2500 m covers 40% of the country (EFAP, 1994; Demel Teketay, 1999; Zerihun Woldu, 1999). The Great East African Rift Valley bisects the plateau into western and eastern highlands. The uplands and highlands west of the Rift Valley are collectively termed as the North-Western highlands and the highland massifs east of the Rift Valley are termed as the South-Eastern Highlands.

The topography and diverse climatic conditions of Ethiopia led to the emergence of habitats that are suitable for evolution.These have led to the occurrence of some unique plant and animal species and their assemblages. As a result, Ethiopia is one of the countries in the world with high level of biodiversity. Owing to the long history of agriculture and the diversity of the environment, Ethiopia is again one of the 12 Vavilov centers of crop genetic diversity (Zerihun Woldu, 2008).

A substantial proportion of the land area in high land Ethiopia was once believed to have been covered by forest (Friis, 1992). However, forest cover in Ethiopia has been declining rapidly due to antropogenic impacts such as uncontrolled expansion of agriculture, overgrazing coupled with illegal harvesting of the forest and other products (Friis, 1992; Shibiru Tedla, 1995; Feyera Senbeta and Fekadu Tefera, 2001; Million Bekele and Leykun Berhanu, 2001).

Furthermore, biodiversity resources along with their habitats are rapidly disappearing in the country (Demel Teketay, 1992; Tadesse Woldemariam and Demel Teketay, 2001; Tadesse Woldemariam *et al.*, 2002; Tadesse Woldemariam, 2003; Feyera Senbeta, 2006; Feyera Senbeta and Denich, 2006). Ensermu Kelbessa *et al.*, (1992) also stated that in Ethiopia, limitations to the opportunities for income generation caused by ecological and socioeconomic constraints forced people to cultivate marginal lands and allow overgrazing and the felling of trees, thus catalyzing a spiral of environmental degradation and deforestation. The overall result of this environmental degradation in Ethiopia, whether at a local or ecosystem level, leads to desertification and its manifestations are eventually becoming the overriding cause for the loss of biodiversity. These disruptions are meant that much endemic biodiversity has been lost and more is threatened (Zerihun Woldu, 2008).

Most of the existing forest patches in Ethiopia are in a secondary state of development (Friis and Mesfin Tadesse, 1990; Tamrat Bekele, 1993). According to Tilaye Nigussie (1997) and Kumlachew Yeshitila and Tamrat Bekele (2002), most of the remaining primary forests of Ethiopia are confined to less accessible areas of the country. These remnant natural forests are continuously threatened by commercial plantations of teas and coffees. EFAP (1994) estimated the annual loss of high forest area in Ethiopia between 150,000 and 200,000 ha. McKee (2007) also indicated rate of deforestation at 146,000 ha/year. From 1990 – 2005, Ethiopia has lost 14% of its forest cover or around 2.1 million ha. Deforestation has increased by 10.4 percent since the close of the 1990s in Ethiopia (Wikipedia, 2010).

Various estimates of the forest cover of Ethiopia were reported. Accordingly, the forest cover in Ethiopia is declining and estimated to be less than 4% compared, for example, with an average of 20% for sub-Saharan Africa (Earth Trends, 2007; WBISPP, 2004). Reusing (1998 & 2000) using LANDSTAT/MSS showed that the extent of forest/vegetation cover of Ethiopia based on density classes, i.e., closed high forest, slightly disturbed high forest and heavily disturbed high forest. Therefore, the forest cover of Ethiopia (including all the three types) was 1.41% in 1996-1997.

Loss of forest cover and biodiversity due to human-induced activities is a growing concern in many parts of the world (Feyera Senbeta and Demel Teketay, 2003). To alleviate such losses, due attention is given to the establishment of natural reserves around the world (Groombridge, 1992; Pimbert and Pretty, 1995; WRI *et al.*, 1998). In addition, generation of scientific knowledge through the studies of floristic composition and structural analysis could be one of the intervention mechanisms to contribute towards the conservation of vegetation resources and the associated biodiversity. It is, thus, equally important to study and document the remaining vegetation resources to base conservation and sustainable utilization on scientific knowledge.

Komto Forest, one of the 58 National Forest Priority Areas (NFPAs), was also established for a similar purpose though it is not well managed and most of the forest area is degraded and converted to agricultural land. Yonas Yemishaw (2002) stated that all of the NFPAs, invariably, are under extreme pressure from settlement, land-use conversion for farming and grazing, excessive extraction, and neglect in terms of forest management and protection. This might be due to the negligence of the surrounding community and other stakeholders during the establishment of Komto Forest as a protected area. The decision made on the protected areas do not give due concideration to the interests of stakeholders, especially communities who are dependent on the local resources (Feyera Senbeta and Demel Teketay 2003).

According to Hurni *et al.*, 1987; Shibiru Tedla, 1995; Feyera Senbeta and Fekadu Tefera, 2001; Feyera Senbeta and Demel Teketay, 2003, protected areas have been hardly managed in Ethiopia due to population pressure coupled with poor management. Numerous efforts have been made by the government to restore forests, including forest border demarcation, resettlement of people within and outside the forest in confined areas, establishing forest protection committees and check points, afforestation, and prohibiting logging. These all government activities resulted in dead end concerning forest conservation (Veerakumaraan and Aklilu Negussie, 2007).

Feyera Senbeta and Demel Teketay (2003) stated that lack of integration of the local people living around the conservation areas into the conservation efforts is the major constraint to the overall conservation effort in Ethiopia. Because of this, it has now been realized that unless the local community is involved in the conservation effort, the sustainability of forest resource will be under a question (Aklilu Ameha, 2002). Hartmann (2004) again emphasized that the different effort made by the Ethiopian government(s) for afforestation and protection of the remaining forests failed due to lack of participation of the communities in resource management as violation of indigenous institutional rights has also led to great tensions among different forest users. The current government of Ethiopia, however, has started to protect forests through participatory forest management. Therefore, as a strategy for development interventions, the beginning of managing forest together with the local community is essential in fighting forest degradation in Ethiopia (Tsegaye Bekele *et al.*, 2007; Veerakumaraan and Aklilu Negussie, 2007).

1.2 Statement of the Problem

Komto Forest was proposed as a Forest reserve area in 1976 and demarcated as a state forest in 1990 as one of the NFPAs. Though the Forest has been under protection since its demarcation, it ihas been continuously exploited by the surrounding people because of agricultural land expansion, timber harvesting (logging), firewood collection and charcoal production, wood cutting for construction and other purposes. The firewood and charcoal supply for the zonal town, Nekemte, is mainly obtained from this forest area (personal observation). Moreover, little is known about the Forest as there is no floristic and structural study of the forest was made before. Thus, the present study was initiated to generate basic scientific information on the biodiversity (plant species richness) and structure of the forest.

1.3 Objectives

General Objective

- To study the floristic composition and structure of the forest.

Specific Objectives

1. To document the floristic composition of the forest,
2. To analyze the structure of the forest,
3. To classify the forest vegetation into plant community types,
4. To determine the diversity of the different community types,
5. To determine the regeneration status of some woody species,
6. To make phytogeographical comparison of the forest with other similar forests in the country and
7. To assess the status of the vegetation and to make some recommendations on the management and conservation of the forest.

2. LITERATURE REVIEW

2.1 Vegetation of Ethiopia

Vegetation is an assembledge of plants growing together in a particular location. It is the collective plant cover of an area (Jennings *et al.*, 2003). Owing to the extreme variation in climate, terrain, etc. and various ecological systems which are suitable for evolution, Ethiopia possesses one of the largest and most diverse plant genetic and wild life resources. The size of the Ethiopian vascular plants is estimated to be about 6000 species of which about 10% are considered endemic (Ensermu Kelbessa, pers. comm.). Moreover, the country has over 300 tree species which are used for construction and industrial purposes (Million Bekele and Leykun Berhanu, 2001). Ethiopia is also one of the African countries known for high endemism of wild plant and animal species (FAO, 1996). However, the forest cover of Ethiopia at present is much smaller than in the past (Teshome Soromessa, 1997).

The Ethiopian forests and woodlands are repositories and gene pools for several domesticated and/or important wild plants and wild relatives of domesticated plants. For example coffee (*Coffea arabica*) is found in the wild in the moist evergreen montane forests of the south, west and southwest of the country. In addition, forests are important not only for the products that can be harvested from them and for the complex interactions they make with other organisms to build up and/or maintain the complex fabric of biodiversity, but also for preventing erosion and for affecting the climate in a positive way as forests are used in sequestering carbon dioxide (NBSAP, 2005).

Many scholars have attempted to study and describe the vegetation of Ethiopia. Most of the studies, identification and decriptions of this vegetation were undertaken by foriegn travelers since the beginning of the 19th C to the mid 20th C. Just to mention some of them, Pichi-Sermolli (1957) identified 23 vegetation types, Breitenbach (1963) published the indigenous vegetation trees of Ethiopia. Other attempts to describe the vegetation of Ethiopia were also conducted by White (1983), Lissanework Nigatu and Mesfin Tadesse (1989), Friis and Mesfin Tadesse (1990), Ensermu Kelbessa *et al.* (1992), Friis (1992), Tamrat Bekele (1994), Sebsebe Demissew *et al*. (1996), Zerihun Woldu (1999), Friis and Sebsebe (2001), Tadesse Woldemariam (2003), Sebsebe Demissew *et al*. (2004), Teshome Soromessa *et al.* (2004), Feyera Senbeta (2006), Ensermu Kelbessa and Teshome Soromessa (2008) have described the vegetation types of Ethiopia. Based on the results of the studies conducted, the various vegetation types of Ethiopia have been grouped into eight general categories (Ensermu Kelbessa *et al.*, 1992; Sebsebe Demissew *et al*., 1996; Friis and Sebsebe Demissew, 2001; Sebsebe Demissew *et al*., 2004; Sebsebe Demissew and Friis, 2009).

Accordingly, the vegetation of Ethiopia is divided into eight major types: *Desert and Semi-desert Scrubland, Acacia-Commiphora Woodland, Moist evergreen Montane Forest, Low land semi-evergreen forest, Combertum-Terminalia Woodland, Dry evergreen Montane Forest, Afroalpine and Sub-Afroalpine Vegetation* and *Riparian and Wetland Vegetation..*

2.1.1 Moist Evergreen montane forests of Ethiopia

The Moist Evergreen Montane Forest comprises the humid forest in the southeastern plateau, Harenna Forest, (Lissanework Nigatu and Mesfin Tadesse, 1989) and Mana Angetu (Ermias Lulekal *et al.*, 2008) and high forests of the country mainly the southwest forests. Several researchers such as Hailu Sharew, 1982; Lisanework Nigatu and Mesfin Tadesse, 1989; Zerihun Woldu *et al*., 1989; Friis, 1992; Kumlachew Yeshitila and Tamrat Bekele, 2002 Ensermu Kelbessa and Teshome Soromessa, 2008; Woldeyohannes Enkossa, 2008 have studied the composition and structure of this forest vegetation type in southern, southwest and western part of the country and described them on floristic basis.

The Moist Evergreen Montane Forest of west and southwest Ethiopia occurs in Wollega, Illubabor and Kefa. It is found between (500-) 1500-2500 (-2800) m a.s.l with average annual temperature of 18-20^{0}C, and an annual rainfall between 1500 and 2000 (-2700) mm, with rain nearly throughout the year with a maximum from April to October (Friis *et al*., 1982; Friis, 1992; FAO, 1996; Zerihun Woldu, 1999; Tadesse Woldemariam, 2003; NBSAP, 2005; Feyera Senbeta, 2006; Ensermu Kelbessa and Teshome Soromessa, 2008).

The moist evergreen forest ecosystem is the most diverse ecosystem in composition, structure and habitat types (NBSAP, 2005). As a result, large complexes of mountain forest exist forming several distinct vegetation units. Floristically, this forest is rich with a number of endemic species. However, the natural vegetation is threatened by the expansion of commercial coffee plantation. According to NBSAP (2005), human activities cause most striking changes in the Moist Evergreen Montane Forest ecosystem in the form of timber extraction, coffee and tea plantations, agricultural expansion, settlement and deliberate or accidental fire hazards. At present, maize and teff cultivation is also encroaching into parts of the southwestern Ethiopia, which together with highly leached acidic soils and rugged topography intensifies the degradation processes (NBSAP, 2005).

The common species in this forest 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 sur, Maesa lanceolata, Teclea nobilis* and *Bersama abyssinica* (EFAP, 1994; FAO, 1996; Zerihun Woldu, 1999; Demel Teketay, 2002; Tadesse Woldemariam, 2003; NBSAP, 2005; Feyera Senbeta, 2006; Ensermu Kelbessa and Teshome Soromessa, 2008).

2.2 Biodiversity and threats on biodiversity in Ethiopia

Ethiopia still has a rich diversity important to the world in both domesticated and wild plant and animal species that occur in variable and unique micro and macro-ecosystems (FAO, 1996; NBSAP, 2005). A loss in biodiversity due to degradation of environment and other threats to components of ecological systems is the most serious environmental problems Ethiopia is facing at present (FAO, 1996; NBSAP, 2005). This loss in biological diversity ultimately implies economic losses to a country and the world as a whole. The removal of vegetation cover also reduces the quantity of carbon that can be sequestered from the atmosphere (EFAP, 1994) and contribute to the global warming.

The extent of past forest cover on the Ethiopian high lands is evident from the numerous isolated mature forest trees or small patches of forests or woodlands that make conspicuous landmarks on the plateau (Friis, 1992). Large areas with evergreen bushland or farmland mixed with bushland represent formerly forested areas (Friis, 1992).

The original forest cover of Ethiopia is not known. However, there is a decline in forest cover from the original 35% to 16% by the early 1950's. By the early 1980's, it has been estimated that the land area covered by forest had declined to 3.6% and by 1989 to 2.7% and estimated to be 2.4% in 1992 (Million Bekele and Leykun Berhanu, 2001). Reusing (1998 & 2000) calculated the forest cover of Ethiopia to be 1.41% in 1996-1997.

There are many causes of deforestation and forest degradation and they vary by forest type, location and social and economic circumstances. Natural resource degradation, decline in agricultural production, food insecurity, and poverty are all interwoven with each other mutually reinforcing in pushing the rural poor in a down ward spiral (Yonas Yemishaw, 2002). Moreover, high population growth followed by increasing demand for crop and grazing land and wood for fuel and construction and settlement in forests are increasing and have resulted in the conversion of forest land into agricultural and other land use systems. EPA (1998), Desta Hamito (2001), NBSAP (2005) and USAID (2008) also identified the following factors as causes of deforestation. These are:

- Rising demand for tree products, that is, fuelwood, construction wood, fodder etc.
- Conversion of forest land to agricultural land and shifting cultivation, urbanization, etc. For example, in the middle and lower Awash Valley alone (a part of the Afar Region), 45,931 hectares of land have been utilized for irrigated crop production. There is also a big threat to the vegetation as wood is required for construction purposes (EPA, 1998) and
- Expanding population pressure, resulting in actual human and animal population exceeding the carrying capacity of the land.

In addition to the deforestation caused by understandable needs, negligence as well as wanton destruction (such as by fire), do contribute to deforestation. These types of deforestation have become increasingly frequent in the last 20 years or so. For example, the forest fires, which occurred during 1998 and 2000 in Bale, Borana, East Harerge, North Omo zones and other places destroyed an estimated 155,966 ha of forestland (Teshome Soromessa, 2007). Most of the deforestation occurred during the period in which security of land tenure and access to natural resources were undermined by unpopular policy measures such as frequent redistribution of land and restrictions in cutting and utilizing trees, even in one's own backyard. Serious destruction of forests has occurred between the fall of the previous government and the stabilization of the present one (EPA, 1998).

2.3 Plant Community Types

When an ecologist stands on a hilltop and surveys a landscape dominated by natural or semi-natural vegetation in any part of the world, the main differences in pattern visible in the landescap will be those of plant communities (Kent and Coker, 1992). Major distinction among plant communities will be made on the bases of physiognomy or the growth form of the vegetation. Plant communities are conceived as types of vegetation recognised by their floristic composition. The species compositions of communities better express their relationships to one another and environment than any other characteristic (Kent and Coker, 1992).

The plant community can be defined as the collection of plant species growing together in a particular location that show a definite association or affinity with each other (Kent and Coker, 1992) or it is a combination of plants that are dependent on their environment, influence one another, and modify their own environment (Mueller - Dombois and Ellenberg 1974). It is also stated in Mueller-Dombois and Elenberg (1974) that the floristic composition of vegetation includes all species occurring within a plant community. However, most plant communities consist of so many different species which are not unique to a given community. Hence, it is common to use the dominant species in naming plant communities (Kent and Coker, 1992).

2.3.1 Species diversity, richness and similarity

The description of plant community involves the study of species diversity, evenness and similarity. Diversity and equitability of species in a given plant community is used to interpret the relative variations between and within the community and help to explain the underlying reasons for such a difference. The idea of species diversity involves two relatively distinct concepts: species richness and evenness. Species richness refers to the total number of species in a community while evenness is the relative abundance of species within the sample or community (Kent and Coker, 1992). Diversity is, thus, measured by recording the number of species and their relative abundances. The two components may be examined separately or combined in some form of index like the Shannon diversity index. Patterns of plant species diversity have often been noted for prioritizing conservation activities because they reflect the underlying ecological processes that are important for management (Lovett *et al*. 2000; cited in Feyera Senbeta, 2006).

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 (Kent and Coker, 1992). 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). Species diversity index provide information about community composition than simply species richness. Measures of species diversity are usually seen to be key indicators for the wellbeing of ecological systems. Among many of species diversity indices, diversity and evenness are often calculated using Shannon diversity index, which naturally varies between 1.5 and 3.5 and rarely exceeds 4.5 (Kent and Coker, 1992). It is the most widely used index that combines species richness with evenness.

2.4 Regeneration and Recruitment of Vegetation

The recruitment of a seedling population from the available seed relies on environmental sieve (Harper, 1982). Hence, a good understanding of natural regeneration in any plant community requires information on the presence and absence of persistent soil seed banks or seedling banks, quantity and quality of seed rain, durability of seeds in the soil, losses of seeds to predation and deterioration, triggers for germination of seeds in the soil and sources of regrowth after disturbances (Demel Teketay, 2002). In order to understand plant population or species, it is necessary to characterize the strategies adapted in both regenerative (immature) and established (mature) stages in their life cycle (Watkinson, 1997; Getachew Tesfaye and Abiyot Berhanu, 2006).

Different plants experience different regeneration strategies such as formation of vegetative propagules (bulbs, tubers, gemmae), seed production, vegetative expansion (eg. by layering) and seasonal regeneration in a vegetative gap. Accordingly, tropical forest plants regenerate from one or more pathways, i.e. (i) *seed rain*: recently dispersed seeds; (ii) *soil seed bank*: dormant seeds in the soil; (iii) *seedling bank* or *advance regeneration*: established, suppressed seedlings in the understorey; and (iv) *coppice*: root or shoot sprouts of damaged individuals (Garwood, 1989). However, the regeneration status of moist montane forests of southwest Ethiopia is generally lower than that of afromontane forests (Poorter *et al.*, 1996; Taye Bekele *et al.*, 2002).

Patterns of seed/seedling survival depend on several (and possibly interacting) factors such as the inherent properties of seeds such as germination, dormancy and viability, the environmental conditions where seeds land and subsequent changes as well as the presence of seed predators and pathogens determine the length of time which seeds can remain viable in the soil. Therefore, for a successful regeneration, a sufficient volume of viable seeds, appropriate edaphic and climatic conditions for germination and establishment are crucial (Taye Bekele *et al.*, 2002). In addition, according to EFAP (1994), when the forest's resource base is declining, the vitality of regeneration is also reduced.

In mature tropical and temperate forests a very common regenerative strategy was one in which the population of tree seedlings and saplings persist for long periods in extremely stunted or etiolated conditions and a small percent survived to maturity by expanding into canopy gaps where they arise through the senescence and death of established trees (Brown, 1919; Sernander, 1936; cited in Grime, 1979; Harper, 1997). In the population dynamics of such trees, the reservoir of seedlings and saplings functions in a way which is in some respects analogous to that of a seed bank (Grime, 1979).

Following the germination of seeds, the next phase in the process of regeneration by seeds is the development of seedlings. Fenner (1987) and Whitmore (1996) stated that vulnerability of seedlings to hazards from environmental and biotic factors is higher at the early stages of seedling establishment. For example, Ensermu Kelbessa and Teshome Soromessa (2008) stated that some species are unable to establish in the under storey environment while other seedlings and saplings are favored by herbivores. A tree species with no seedling and sapling in a forest is under a threat of local extinction (Taye Bekele *et al.*, 2002). Moreover, Tree species that have been over utilized and lack replacement would eventually disappear from the forest (Ensermu Kelbessa and Teshome Soromessa, 2008). One of the most effective adaptations for ensuring successful seedling establishment is, therefore, possession of a large seed, which provides an ample reserve of nutrients during the period immediately after germination (Foster, 1986).

Seedling recruitment is a bottleneck in the population dynamics of many species of trees. Recruitment reflects not only seed production but also the compound filtering effects of seed dispersal and seedling establishment. Seedlings may fail to occupy a particular site either because seeds do not arrive at the site (dispersal limitation) or because the site is not a suitable environment for establishment (establishment limitation). In general, supply processes such as fecundity of parent trees, together with the factors that affect seedling establishment, are the major determinants of local abundance and diversity of mature trees (Uriarte *et al.*, 2005). In addition, vegetative regeneration of forest gap can be affected by size, shape and orientation of gap to the sun, soil type, topography, soil seed bank. Height and species composition of the surrounding vegetation, extent of damage to vegetation upon formation of the gap, temperature aspect of the gap and its spatial disturbances can also affect vegetative regeneration (Struhsaker, 1997; Gemedo Dale and Masresha Fetene, 2004; Demel Teketay, 2005).

3. MATERIALS AND METHODS

3.1 The Study Area

3.1.1 Location

Komto Forest is administratively located in Wayu Tuka District of East Wollega Zone in Oromia National Regional State, 330 km west of Addis Ababa along Addis Ababa-Gimbi road and 12 km east of Nekemte, the capital town of East Wollega Administrative Zone. It covers an area of about 500 ha. The forest lies in the range of latitudes $9^{0}05.10$’ to $9^{0}06.35$’N and longitude $036^{0}36.47$’ and $036^{0}38.10$’ E (Figure 1).

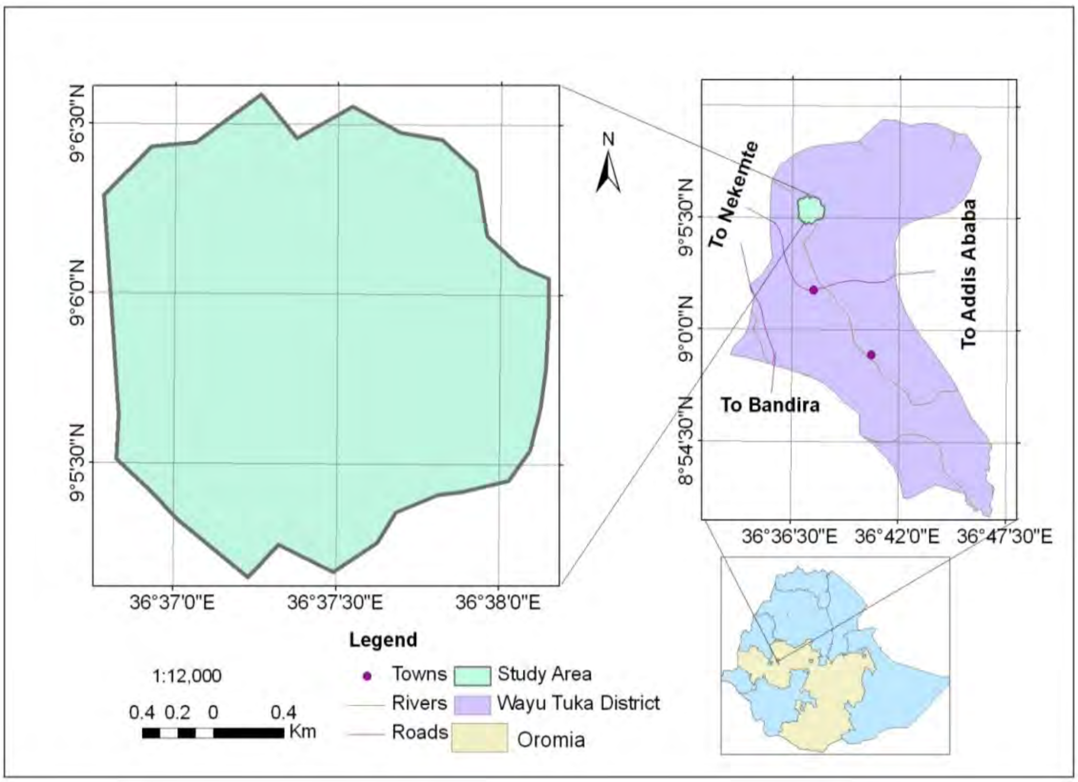

Figure 1: Location Map of Wayu Tuka District and Study area

3.1.2 Topography

Wayu Tuka District is generally characterized by rough topography. It consists of mountains, deep gorges, escarpments and plateaus. The District falls within altitudinal range of 1300 to 3140 m a.s.l. Komto Forest, however, is situated in the intermediate altitudinal range between 2100 and 2482 m a.s.l. on Komto Mountain (GPS reading during field work).

3.1.3 Climate and agroclimatic zones

The rainfall and temperature data for this study were collected from the nearest Meteorological Station, Nekemte, which is about 12 km away from the capital of Wayu Tuka District. The data were collected from 1998- 2007 by National Meteorological Service Agency (NMSA, 2010). Climate diagram was computed by using R for window version 2.10.1 statistical package (R-Development Core Team, 2007).

Wayu Tuka District falls within the southwestern and western unimodal rainfall region of Ethiopia. The annual rainfall on the Ethiopian highlands, in the Southwest and Western, ranges from 1400 mm to 2200 mm (Daniel Gemechu, 1977). Friis (1992) however categorised this part of Ethiopia under areas with even distribution of rainfall throughout the year. Generally, the study area (Komto Forest) is humid and moderately hot. The mean annual temperature is about 18.8^0C and the mean minimum and maximum temperatures are 12.2^0C and 27.9^0C respectively. There is a slight difference in the temperature throughout the year. The hottest months are from February to October with maximum temperature record in February and May (27.9^0C) and the coldest months range from November to January with minimum temperature of 12.2^0C in December and January (Figure 2).

The mean annual rainfall of the study area is 2067 mm. The rainfall pattern is unimodal, with little or no rainfall in January and February, gradually increasing to peak period between May and October, and decreasing in November and December (Figure 2). Three agroclimatic zones (from 500-1500 m a.s.l low land, from 1500-2500 m a.s.l middle altitude and from 2500-3500 m a.s.l high land) (EFAP, 1994), can be recognized in Wayu Tuka District. Accordingly, the proportion of the three agroclimatic zones in the District is highland (37.66 %), Mid-altitude (49.21 %) and lowland (13.12 %) (W.D.A.R.D.O, 2009).

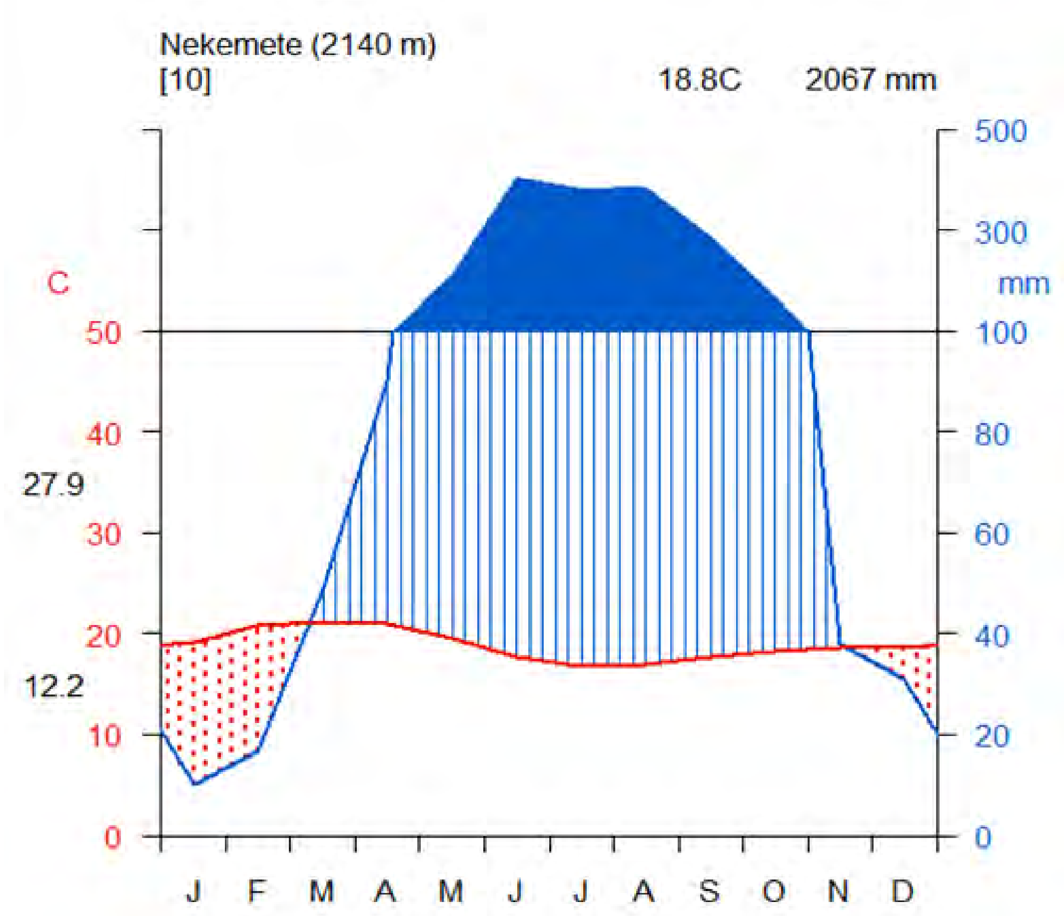

Figure 2: Climatic diagram of Nekemte Town

Source: NMSA, 2009 (1998-2007).

3.1.4 Soil

Nature and management of Ethiopian soils have been discussed by Mesfin Abebe (1998). Accordingly, Oxisols occur in western and southwestern Oromia as in Wollega, Ilu Ababora, Jima, etc with annual rainfall of 1500-2000 mm (Ochtman *et al.*, 1977; cited in Mesfin Abebe, 1998). In addition, Alfisols and Ultisols occur in the humid west part of the country (Mesfin Abebe, 1998). For example, a type of Ultisols was derived from volcanic ejecta around Nekemte in Guto Gida District (Eyilachew, 1993; cited in Mesfin Abebe, 1998). This area coincides with the study area, Wayu Tuka District and Komto Forest. Demel Teketay (2002) also stated that dry Vertisols and Inceptisols are found in the western part of Ethiopia and in southwestern Wollega; soils are deep and belong to the orders Oxisols and Ultisols. The major soil types and their spatial coverage in the District are clay loom 17,371.68 ha, sandy 10,133.49 ha and clay 1,447.64 ha which are suitable for agriculture such as cereal crops: maize, sorghum, and TEFF production in the District (W.D.A.R.D.O, 2009 E.C.).

3.1.5 Human population

Wayu Tuka District was established recently by separating it from Guto Wayu District in 2006. Because of this, it is difficult to obtain population data of relatively longer time in the past. However, the 2007 population and housing census result indicated that the total human population of the District was 66,194 (32,391 males and 33,803 females), with 4.56 % urban dwellers. The rest of the population, 95.44 %, is rural (PCC, 2008).

3.1.6 Land use and agriculture

The proportion of arable, grazing and forest lands in Wayu Tuka District was 55.16%, 3.18% and 11.95% respectively (W.D.A.R.D.O., 2009). The remaining land area is either degraded, built-up or serves other purpose (Table 1). The dominant agriculture in Wayu Tuka District is mixed farming. Livestock production and subsistence agriculture form the major livelihoods of the rural community. The most widely cultivated crops are cereal crops such as maize, wheat, sorghum, TEFF, barley, oats, millet, pulses (horse beans), and oil seeds (NOUG). Honey production is also practiced in the forest area.

Table 1: Land use pattern of Wayu Tuka District

No.	Land use Type	Area in hectare	%
1	Potential arable land	15,971.50	55.16
	➢ For annual crop production	15,444.50	53.34
	➢ For perennial crop production	527	1.82
2	Pasture land (grazing land)	921.665	3.18
3	Degraded /barren area	484.195	1.67
4	Forests	3383.665	11.95
	➢ Natural forests	2470.785	8.53
	➢ Man made forests	912.88	3.15
5	Shrub land	1135.695	3.94
6	Others	7056.075	24.37
	Total	**28,952.795**	**100**

Source: W.D.A.R.D.O. (2009)

3.1.7 Vegetation

The vegetation of the study area (eastern highlands of Wollega) is broad-leaved and evergreen moist forests with important tree species in the forests including *Pouteria adolfi-friederici*, *Syzygium guineense* ssp. *afromontanum*, *Apodytes dimidiata*, *Prunus africana*, *Albizia gummifera*, *Albizia schimperiana*, *Croton macrostachyus*, *Cassipourea malosana*, *Ekebergia capensis*, *Euphorbia ampliphylla*, *Ficus sur* and shrubs e.g. *Maesa lanceolata*, *Teclea nobilis,* and *Bersama abyssinica* (Demel Teketay, 2002). This vegetation type is observed in Wayu Tuka District and Komto Forest (Plate 1). There is also lowland vegetation type in the District although not in Komto Forest. The high forest area, however, has been cleared for timber harvesting and charcoal production (Plate 2) and agricultural intensification which resulted in bushland and farm land (personal observation and communication with inhabitants of the area) (Plate 3).

Plate 1: The vegetation of Komto Forest (a) and a mature *Pouteria adolfi-freiderici* tree (b)

Plate 2: *Pouteria adolfi-friedericii* tree ready for timber production (a) and Charcoal production (b)

Plate 3: Bushland formed as a result of deforestation

3.1.8 Wildlife

The Forest vegetation of Wayu Tuka District hosts various species of wild animals including mammals, birds, reptiles and amphibians. Some of the common mammals are spotted hyena, abyssinian black and white colobus monkey, common jackal, blue monkey, bushbuck, common duicker, aardvark, olive baboon, hare, vervet monkey, crested porcupine, etc. However, the wildlife populations of these animals are under severe threat due to deforestation and habitat fragmentation mainly because of human encroachment.

3.1.9 Drainage

Wayu Tuka District, with an altitudinal range between 1300 and 3140 m a.s.l and with various topographic land forms, is endowed with numerous streams and rivers such as Beseka, Wachu, Adiya, Tato, Oda, Yaya Jabo and Alaltu which are permanently flowing through out the year. Some of these rivers are extensively used for irrigation purpose. Others also provide the surrounding people with drinking water and small scale irrigation.

3.2 Method

3.2.1 Reconnaissance survey

Reconnaissance survey was made during the last week of September, 2009 in order to obtain an impression of the site conditions and to select sampling sites.

3.2.2 Sampling design

Systematic sampling following Kent and Coker (1992) and Muller-Dombois and Ellenberg (1974) was used for the study. Sampling sites were arranged along transects in eight (E, NE, N, NW, W, SW, S, SE) directions from the peak of the mountain Komto down to the base and to the surrounding plain and a transect of one quadrat at the top of the mountain. Each of the eight transects contain different number of 20 m x 20 m (400 m^2) plots for woody species at a distance of 200 m from each other depending on the length of the transect. A total of 53 quadrats were laid for vegetation data collection. (The number of plots in each transects along with its location and altitude is given in Appendix I). In addition, five 1 m x 1 m sub plots, one at each corner and one at the center of the main plot were also laid to sample herbaceous plants.

3.2.3 Vegetation data collection

Data collection was conducted from October 15 to November 25, 2009. A complete list of trees, shrubs and herbs including vascular epiphytes was made from the systematically selected plots along each transect. Species occurring within 10 m distance from the plots boundaries were also recorded as present for floristic composition. Vernacular names of species were recorded during field work. Specimens of all vascular plant taxa were collected, pressed, dried and brought to the National Herbarium (ETH), Addis Ababa University for identification and storage. The nomenclature of the taxa follows Flora of Ethiopia and Eritrea (FEE).

In each plot, the following structural attributes were also recorded for all woody plants. These are diameter and height. Diameter was measured for all individual trees and shrubs having DBH (Diameter at Breast Height) greater than 2.5 cm using a diameter tape. If the tree branched at breast height or below, the diameter was measured separately for the branches and averaged. Trees and shrubs with DBH less than 2.5 cm were counted. Height was measured for individual tree and shrub with DBH greater than 2.5 cm using calibrated stick. Where topographic features made difficult to measure height of trees and shrubs, it was estimated visually. The presence-absence and cover abundance data, defined here as the proportion of area in a quadrat covered by every species recorded and gathered from each quadrat were later converted to cover abundance values using the modified 1-9 Braun-Blanquet scale (van der Maarel, 1979) as follows.

- 1: Rare, generally one individual;
- 2: Occasional, with less than 5% cover of the total;
- 3: Abundant, with less than 5% cover of the total;
- 4: Very abundant, with less than 5% cover of the total;
- 5: 5-12% cover of the total area;
- 6: 12-25% cover of the total area;
- 7: 25-50% cover of the total area;
- 8: 50-75% cover of the total area;
- 9: 75-100% cover of the total area;

Investigation of the seedling and sapling density and regeneration of some selected species has been carried out within the same quadrat. Partition of the major quadrats (400 m^2) was made into four, each 100 m^2 (10 m X 10 m), so as to make seedling counting easier. In each of these quadrats, the number of all seedlings that are less than 1 m in height were recorded. Individuals attaining 1 m and above with DBH less than 2.5 cm were considered as sapling and counted. Environmental variables such as altitudes and geographical coordinates were also measured for each plot using Garmin 72 GPS (Geographical Position System).

3.2.4 Data analysis

3.2.4.1 Multivariate analysis of vegetation data

Classification by means of hierarcical cluster analysis is the most common multivariate technique to analyze community data. Cluster analysis helps to group a set of observations (here plots or vegetation samples) together based on their attributes or floristic similarities (Kent and Coker 1992; McCune and Grace 2002). Accordingly, a hierarchical cluster analysis was performed using PC-ORD for windows version 5.0 (McCune and Mefford, 1999) to classify the vegetation into plant community types based on abundance data of the species in each quadrat and the Relative Euclidean Distance (RED) measures using Ward's method were used in the current study. The data matrix contained 53 plots and 114 species collected from the sample plots. The Euclidean Dstance was used because it eliminates the differences in total abundance among sample units and the Ward's method was used because it minimizes the total within group mean of squares or residual sum of squares (van Tongeren, 1995; McCune and Grace, 2002).

The clusters were further tested for the hypothesis of no difference between the groups using the multi-response permutation procedure (MRPP). Dufren and Legender's (1997) method of calculating species indicator values was used to detect the values of different species. Indicator species are defined as the most characteristic species of each group found mostly in a single group of the typology and present in the majority of the sites belonging to that group (Dufren and Legender, 1997). Indicator values are measures of the fidelity of the occurrence of a species in a particular group (McCune and Mefford, 1999) and its value ranges from zero (no indication) to 100 (perfect indication). Indicator values were also tested for statistical significance using Monte Carlo technique. The clusters were designated as plant community types and given names after one or two dominant or characteristic species. A species is considered as an indicator of the group when its indicator value is significantly higher at $P<0.05$.

3.2.4.2 Diversity and similarity indices

Biological diversity can be quantified in different ways. Shannon-Wiener diversity index, species richness and Shannon's evenness were computed to describe species diversity of the plant community types in the vegetation. Shannon - Wiener diversity index is the most popular measure of species diversity because it accounts both for species richness and evenness, and it is not affected by sample size (Kent and Coker, 1992; Krebs, 1999). Shannon-Wiener diversity index was calculated as follows.

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \text{ Where,}$$

- **H'** = Shannon diversity index**,**
- **S** = the number of species**,**
- $\mathbf{P_i}$ = the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of total cover and
- **ln** = logbase_n

Evenness (Equitability) **J=H'/H'max**, where:

- **J**=Evenness,
- **H**'=Shannon-Wiener diversity index and
- **H'max**=ln s 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 or the quadrats. Similarly, the higher the value of H', the more diverse the community or the quadrat are.

Sorensen's similarity index was used to determine the pattern of species turnover among successive communities and to compare the forest with other similar forests in the country. It is described using the following formula (Kent and Coker, 1992).

$$\mathbf{S_s = 2a/ (2a+b+c),}$$

Where:

- $\mathbf{S_s}$ = Sorensen's similarity coefficient
- **a** = Number of species common to both samples;
- **b** = Number of species in sample 1;
- **c** = Number of species in sample 2

3.2.2.3 Structural analysis

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

IVI = Relative Density (abundance) + Relative Dominance (basal area) + Relative Frequency, Where:

- RD = the number of all individuals of a species/the total number of all individuals (DBH > 2.5 cm) X 100;
- RF = the number of plots where a species occurs/ the total occurrence of all species in all of the plots X 100.
- RDO= Dominance of a species/Dominance of all species X 100 (DBH > 2.5 cm) and
  - Dominance=Mean basal area/tree X the number of trees of a species

Basal area (BA) was calculated using DBH as follows:

$BA = \pi d^2/4$, where, π= 3.14; d = DBH (m).

4. RESULT AND DISCUSSION

4.1 Plant Species Composition of Komto Forest

A total of 180 plant species belonging to 151 genera and 66 families were recorded and identified from Komto Forest (Appendix II). Out of these, 42 species (23.33%) were trees, 43 species (23.88%) were shrubs, 62 species (34.44%) were herbs, 11 (6.11%) grasses and sedges, 14 species (7.77%) were lianas, 7 species (3.88%) were ferns and 1 (0.55%) species was a woody hemi parasite (Figure 4). Of all the families, Fabaceae and Asteraceae were the most dominant with each contributing 17 species (9.44%) to the total and followed by Lamiaceae, Malvaceae and Poaceae with 10 species (5.55%), 9 species (5 %), and 9 (5%), respectively. Euphorbiaceae with 8 (4.44%) species and Acanthaceae and Celastraceae each with 6 (3.33%) species were also very important families in terms of species richness. Thirty six families consisted of only 1 species each. The number of species and genera for the rest of the families are given in Table 2. In addition, of all the species collected, 89.44% were dicots, 6.66% were monocots and 3.88% were ferns. No Gymnosperm was identified in the Forest. The large percentage of dicots is due to their evolutionary advancement.

Table 2: Families with their corresponding number of genera and species.

	Genera		**Species**	
Family	**Number**	**%**	**Number**	**%**
Fabaceae	14	9.27	17	9.44
Asteraceae	11	7.28	17	9.44
Poaceae	8	5.29	9	5.00
Lamiaceae	10	6.62	10	5.55
Malvaceae	5	3.31	9	5.00
Euphorbiaceae	6	3.97	8	4.44
Acanthaceae	5	3.31	6	3.33
Celastraceae	2	1.32	6	3.33
Urticaceae	3	1.98	4	2.22
Asclepiadaceae	4	2.65	4	2.22

	Genera		Species	
	Number	**%**	**Number**	**%**
Cucurbitaceae	5	3.31	5	2.77
Oleaceae	3	1.98	4	2.22
Rosaceae	3	1.98	4	2.22
Rubiaceae	4	2.65	4	2.22
Solanaceae	2	1.32	4	2.22
Rhamnaceae	3	1.98	3	1.66
Rutaceae	3	1.98	3	1.66
Scrophulariaceae	3	1.98	3	1.66
Tiliaceae	3	1.98	3	1.66
Amaranthaceae	2	1.32	2	1.11
Balsaminaceae	1	0.66	2	1.11
Cyperaceae	2	1.32	2	1.11
Dracaenaceae	1	0.66	2	1.11
Loganiaceae	2	1.32	2	1.11
Meliaceae	2	1.32	2	1.11
Moraceae	1	0.66	2	1.11
Myrsinaceae	2	1.32	2	1.11
Polygonaceae	2	1.32	2	1.11
Pteridaceae	2	1.32	2	1.11
Ranunculaceae	2	1.32	2	1.11
Others	36	23.18	36	19.44
Total	**151**	**100**	**180**	**100**

Analysis of the habit or growth forms of species recorded from Komto Forest was performed (Figure 3). Accordingly, the highest proportion (34.44%) was herbs. This was followed by shrubs (23.88%) and trees (23.33%). In addition, lianas, grasses and sedges and ferns comprised of 8.09%, 6.11% and 4.04% of the total, respectively (Figure 3).

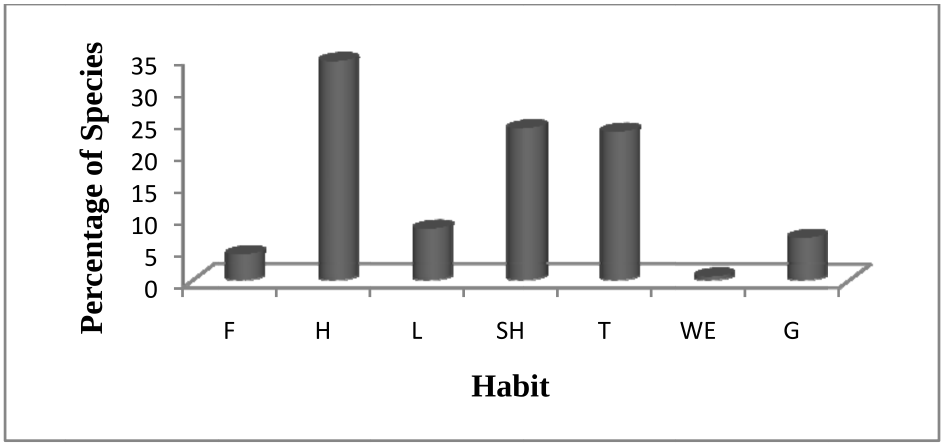

Figure 3: Habit of Plants in Komto Forest (F=Fern, H=Herb, L=Liana, SH=Shrub, T=Tree, G=Grasses and Sedges and WE=Woody Epiphyte/Hemiparasite)

Out of the 180 plant species collected from Komto Forest, 31 were new records for Wollega (WG) floristic region in the flora of Ethiopia and Eritrea (Table 3). These species belong to 28 genera and 21 families with 12 (38.71%) herbs, 6 (19.35) grasses and sedges, 6 (19.35%) shrubs, 3 (9.67%) lianas and 3 (9.67%) tree species.

Table 3: Species not reported from Wollega floristic region (WG) on Flora of Ethiopia and Eritrea. (S= Shrub, G= Grass & Sedge, H= Herb, L= Liana, T= Tree)

No.	**Species Name**	**Family**	**Growth form**	**Vernacular Name (Afaan Oromoo)**
1	*Abutilon mauritianum*	Malvaceae	S	
2	*Achyrospermum schimperi*	Lamiaceae	S	
3	*Andropogon abyssinicus*	Poaceae	G	Baallammii
4	*Ceropegia sobolifera*	Asclepiadaceae	L	
5	*Conium maculatum*	Apiaceae	H	
6	*Crepis foetida*	Asteraceae	H	

No.	Species Name	Family	Growth form	Vernacular Name (Afaan Oromoo)
7	*Crotalaria rosenii*	Fabaceae	S	
8	*Cynodon dactylon*	Poaceae	G	Coqorsa
9	*Cynoglossum amplifolium*	Boraginaceae	H	
10	*Cyperus distans*	Cyperaceae	G	Qunnii
11	*Digitaria velutina*	Poaceae	G	Daggoo
12	*Dryopteris inaequalis*	Dryopteridaceae	H	
13	*Euphorbia ampliphylla*	Euphorbiaceae	T	Adaamii
14	*Impatiens tinctoria* ssp. *abyssinica*	Balsaminaceae	H	Hansoosillaa Gogorrii
15	*Isoglossa somalensis*	Acanthaceae	H	
16	*Kalanchoe densiflora*	Crassulaceae	H	
17	*Lagenaria abyssinica*	Cucurbitaceae	H	Buqqee Seexanaa
18	*Leptadenia arborea*	Asclepiadaceae	L	
19	*Maytenus addat*	Celasteraceae	T	Kombosha
20	*Olea capensis* ssp. *macrocarpa*	Oleaceae	T	Gagamaa
21	*Panicum hochstetteri*	Poaceae	G	
22	*Panicum nervatum*	Poaceae	G	
23	*Pteris catoptera*	Pteridaceae	Fern	
24	*Solanecio gigas*	Asteraceae	S	Jilma Jaldeessaa
25	*Solanum incanum*	Solanaceae	SH	Hiddii Loonii
26	*Solanum marginatum*	Solanaceae	SH	Hiddii Hongorcaa
27	*Tagetes minuta*	Asteraceae	H	
28	*Tagetes patula*	Asteraceae	H	
29	*Tiliacora troupinii*	Menispermaceae	L	Hidda Liqixii
30	*Trifolium semiplosum*	Fabaceae	H	Siddisa
31	*Urtica simensis*	Urticaceae	H	Gurgubbee

4.1.1 Endemism

Komto Forest contains a number of flowering plant species that are endemic to Ethiopia. Endemic plant species of Ethiopia and their level of threat have been given in Ensermu Kelbessa *et al*. (1992) and Vivero *et al*. (2005). Accordingly, 18 (10%) endemic species, some of which are in the IUCN Red Data List, were identified in Komto Forest. Based on available literature (Vivero *et al.*, 2004; Vivero *et al.*, 2005; Vivero *et al.*, 2006), the endemic species and the level of their threat are given in Table 4.

Table 4: Endemic species in Komto Forest (EN= Endangered, LC= Least concerned, NT= Near threatened, VU= Vulnerable, CR= Critically endangered)

No.	Scientific Name	Family	Status
1	*Acalypha marissima*	Euphorbiaceae	EN
2	*Ceropegia sobolifera*	Asclepiadaceae	CR
3	*Crassocephalum macropappum*	Asteraceae	LC
4	*Crotalaria rosenii*	Fabaceae	NT
5	*Echinops longisetus*	Asteraceae	LC
6	*Erythrina brucei*	Fabaceae	LC
7	*Justicia diclipteroides* ssp. *aethiopica*	Acanthaceae	NT
8	*Lippia adoensis*	Verbenaceae	LC
9	*Maytenus addat*	Celestraceae	NT
10	*Millettia ferruginea* ssp. *ferruginea*	Fabaceae	LC
11	*Phragmanthera macrosolen*	Loranthaceae	LC
12	*Rhus glutinosa*	Anacardiaceae	LC
13	*Satureja paradoxa*	Lamiaceae	NT
14	*Solanecio gigas*	Asteraceae	LC
15	*Tiliacora troupinii*	Menispermaceae	VU
16	*Urtica simensis*	Urticaceae	LC
17	*Vepris dainellii*	Rutaceae	NT
18	*Vernonia leopoldi*	Asteraceae	LC

4.1.2 Commercially important tree species

Komto Forest also contained 11 (45.83%) out of 24 major commercial indigenous tree species reported by EFAP (1994) and Million Bekele and Leykun Berhanu (2001). These tree species include *Albizia gummifera, Albizia schimperiana, Pouteria adolfi-friederici, Apodytes dimidiata, Celtis africana, Croton macrostachyus, Ekebergia capensis, Hagenia abyssinica, Olea welwitschii, Prunus africana* and *Syzygium guineense* ssp. *afromontanum*.

4.2. Vegetation Classification

Four plant communities were derived from the hierarchical cluster analysis (Figure 5). The test statistics ***T*** value for the four groups were -18.005 (P<0.001), highly significant, and the agreement statistics ***A*** was 0.099. The test statistics ***T*** describs the separation between the groups and the more negative ***T*** value, the stronger the separation. The agreement ***A*** describes within group homogeneity, and falls between 0 and 1. When all items within groups are identical, ***A***=1 and 0 when the groups are heterogenous. In community ecology, values of ***A*** (agreement) are commonly below 0.1 (McCune and Mefford, 1999). From this result, therefore, the null hypothesis of no difference among groups can be rejected. In the result, the probability value refers to Monte Carlo tests, while values under each group indicate the fidelity of occurrence of a species within a particular group. Bold values indicate significant indicator value (P*<0.05) in each group (Table 5; Appendix IV).

Community names were given after one or two species that had higher indicator values. The latter distinguished the community by their high relative abundance and relative frequency. In all observed plant communities, species with higher indicator values are those that were easily observed repeating themselves in associations. Thus the identified groups are more or less conincidting with the natural associations that any one can observe while crossing through the forest. The four plant communities identified were: *Achyrospermum schimperi-Croton macrostachyus* (Community type 1), *Solanecio gigas-Ficus sur* (Community type 2), *Justicia schimperiana-Acanthus eminens* (Community type 3) and *Periploca linearifolia-Dracaena afromontana* (Community type 4).

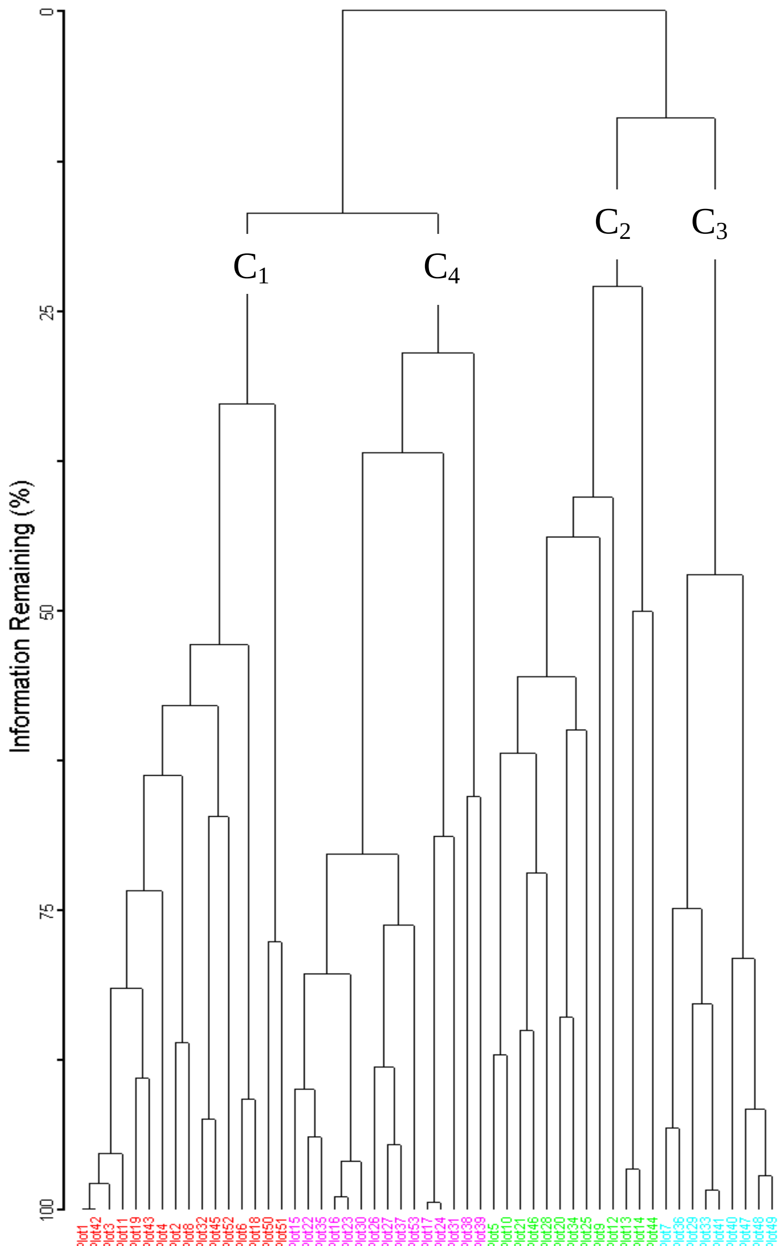

Figure 4: Dendrogram of the vegetation data obtained from hierarchical cluster analysis of Komto Forest using Ward's method and Euclidean distance. The level of grouping was based on about 20 % Information remaining. (C_1= Community type 1, C_2= Community type 2, C_3= Community type 3 and C_4= Community type 4)

C_1: Plots 1, 2, 3, 4, 6, 8, 11, 18, 19, 32, 42, 43, 45, 50, 51 and 52.

C_2: Plots 5, 9, 10, 12, 13, 14, 20, 21, 25, 28, 34, 44 and 46.

C_3: Plots 7, 29, 33, 36, 40, 41, 47, 48 and 49.

C_4: Plots 15, 16, 17, 22, 23, 24, 26, 27, 30, 31, 35, 37, 38, 39 and 53.

4.2.1 *Achyrospermum schimperi-Croton macrostachyus* Community type

This community type was represented by 16 quadrats and 89 species. The community had five indicator species (*Achyrospermum schimperi, Croton macrostachyus, Rytigynia neglecta, Vernonia amygdalina and Hippocratea goetzei*) with significant indicator values (Table 5). The altitudinal range of this community was from 2167-2357 m a.s.l. Woody species (trees, shrub and lianas) associated with this community are *Clausena anisata, Erythrococca trichogyne, Bersama abyssinica, Vernonia auriculifera, Maesa lanceolata, Rubus apetalus, Canthium oligocarpum, Allophylus abyssinicus, Vepris dainellii, Cassiporea malosana, Hagenia abyssinica, Millettia ferruginia* ssp. *ferruginia, Combretum paniculatum, Leucas martinicensis*, and *Ritchiea albersii* (Appendix IV).

Herbs such as *Hypoestes forskaolii, Impatiens hochstetteri, Kalanchoe densiflora, Acalypha marissima, Drymaria cordata, Eriosema scioanum, Cynoglossum amplifolium, Tagetes minuta,* and *Digitaria velutina* are the dominant in the herb layer of this community.

4.2.2. *Solanecio gigas-Ficus sur* Community type

This community comprised of 13 quadrats and 71 species. The community is distributed between the altitudinal ranges of 2184 and 2380 m a.s.l. This community has four indicator species (*Solanecio gigas, Ficus sur, Pouteria adolfi-friederici* and *Dracaena steudneri*) (Table 5). *Ficus sur* and *Pouteria adolfi-friederici* are the emergent trees of this community type. Other trees, shrubs and lianas associated with this community include *Albizia schimperiana, Albizia gummifera, Allophylus abyssinicus, Bersama abyssinica, Brucea antidysenterica, Cassipourea malosana, Celtis africana, Maesa lanceolata, Olea capensis* ssp. *macrocarpa, Olea welwitschii, Psychotria orophila, Rubus steudneri, Rytigynia neglecta, Solanum anguivi, Abutilon martinianum, Acanthus eminens* and *Clematis simensis* (Appendix IV).

The herb layer is composed of *Achyranthes aspera, Cyathula uncinulata, Achyrospermum schimperi, Desmodium repandum, Girardinia diversifolia, Mimulopsis solmsii, Bidens ghedoensis, Momordica foetida, Pteris catoptera, Vigna vexillata* and *Pteridium aquilinum*.

4.2.3 *Justicia schimperiana-Acanthus eminens* community type

This community type was distributed and is situated at altitudinal ranges from 2180 to 2313 m a.s.l. The community is comprised of 9 quadrats and 62 species. The indicator species characterizing this community are *Justicia schimperiana, Acanthus eminens, Erythrococca trichogyne* and *Landolphia buchanani* (Table 5). The other woody species (trees, shrubs and lianas) associated with this community include *Pittosporum viridiflorum, Urera hypselodendron, Syzygium guineense* ssp. *afromontanum, Teclea nobilis, Bersama abyssinica, Brucea antidysenterica, Calpurnia aurea, Clausena anisata, Clematis simensis, Cyphostemma adenocaule, Embelia schimperi, Dregia schimperi, Ocimum lamifolium, Hippocratea africana, Crotalaria mildbraedii, Vernonia auriculifera, Croton macrostachyus, Flacourtia indica, Macaranga capensis, Maytenus gracilipes, Maytenus addat, Chionanthus mildbraedii* and *Vepris dainellii* (Appendix IV).

Herbs such as *Cyathula uncinulata, Achyrospermum schimperi, Achyranthes aspera, Hypoestes forskaolii, Justicia declipteroides* ssp *aethiopica* and *Tragia brevipes* are also common in this community.

4.2.4 *Periplocca linearifolia-Dracaena afromontana* community type

This community is dominated by the woody climber, i.e. *Periplocca linearifolia*. The other indicator species with significant indicator values are *Dracaena afromontana, Cyperus distans, Hibiscus macranthus, Euphorbia ampliphylla and Solenostemon autranii* (Table 5). This community type lies along the altitudinal range of 2256 to 2482. Only three quadrats in this community are below 2325 m a.s.l. indicating that this community occupied the higher altitude of the study area. Fifteen quadrats and 79 species were encountered. Along with the above indicator species, *Apodytes dimdiata, Abutilon longicuspe, Dombeya torrida, Prunus africana, Maytenus undata, Ekebergia capensis, Asparagus africanus, Allophylus abyssinicus, Syzygium guineense* ssp. *afromontanum, Rubus steudneri, Vepris dainellii, Clerodendrum myricoides, Sparmannia ricinocarpa, Schefflera abyssinica, Rhus glutinosa* and *Premna schimperi* are common woody species of this community (Appendix IV).

Solenostemon autranii, Panicum hochstetteri, Setaria megaphylla, Pteridium aquilinum, Zhneria scabra, and *Isoglossa somalensis* are the dominant herbs of the community.

Table 5: 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).

	Communities				
Name of Species	**1**	**2**	**3**	**4**	**P***
Achyrospermum schimperi	**41**	11	18	0	0.0022
Croton macrostachyus	**40**	10	24	7	0.0050
Rytigynia neglecta	**40**	20	9	4	0.0066
Vernonia amygdalina	**30**	3	0	2	0.0176
Hippocratea goetzei	**25**	0	0	0	0.0256
Solanecio gigas	4	**68**	3	2	0.0002
Ficus sur	2	**56**	1	2	0.0004
Pouteria adolfi-friederici	0	**41**	9	6	0.0128
Dracaena steudneri	1	**28**	3	3	0.0262
Justicia schimperiana	10	10	**54**	8	0.0002
Acanthus eminens	7	20	**48**	15	0.0002
Erythroccoca trichogyne	25	4	**38**	2	0.0106
Landolphia buchananii	1	0	**32**	3	0.0064
Periploca linearifolia	4	1	0	**41**	0.0024
Dracaena afromontana	0	1	2	**37**	0.0034
Cyperus distans	0	0	0	**32**	0.0048
Hibiscus macranthus	0	0	0	**27**	0.0178
Euphorbia ampliphylla	0	0	1	**25**	0.0252
Solenostemon autranii	0	0	0	**20**	0.0408

4.3 Species Diversity, Evenness and Richness of the Plant Communities

The highest species richness was observed in community one while community four was with maximum diversity (Table 6). The possible reason for high species richness of community 1 may be altitudinal factor because intermediate altitude could be associated with optimal conditions of environmental factors that favor vegetation growth. Community four was with the highest diversity because its species are evenly distributed although relatively fewer species were recorded (Table 6). Community type 3 exhibited the least species richness and diversity (Table 6). As the community lies along the margin of the forest (easily accessible), anthropogenic impacts such as selective removal of economically important trees, grazing by live stock and other environmental factors such as aspect, slop etc could contribute for low species richness and diversity. For example, Livestocks were observed in the forest margin during field study (Plate 4). Community type 2 was with intermediate richness and diversity but lower than communities 1 and 4 (Table 6).

Table 6: Shanon Wiener Diversity Index

Communities	Average altitude (m a.s.l)	Species Richness	Diversity Index (H')	H'max (Ln S)	Evenness (H'/H'max)
I	2274.4	89	3.830	4.49	0.851
II	2299.3	71	3.606	4.26	0.846
III	2244	62	3.354	4.13	0.813
IV	2351.4	79	3.861	4.37	0.883

Plate 4: Livestock grazing in the forest margin

4.4 Similarity among plant communities

Sorenson's similarity coefficient was used to determine the similarities among plant communities (Table 7). Accordingly, Communities 2 and 3 had the highest similarity ratio (Table 6). This could be associated to slope, aspect, the anthropogenic and other environmental factors such as soil type and properties which were not considered in this study. The least similarity was exhibited by communities 1 and 4 (Table 7) may be because of variation in altitude, slope, aspect and other environmental factors.

Table 7: Sorensen similarity coefficient among community types

Communities	**1**	**2**	**3**	**4**
1				
2	0.71			
3	0.75	**0.767**		
4	0.699	0.733	**0.766**	

4.5 Structure of the Forest

4.5.1 Tree and Shrub density

Tree and shrub density, expressed as the number of individuals with DBH greater than 2.5 cm was 952.83/ha and those individuals with DBH between 10 and 20 cm and with DBH greater than 20 cm were 330/ha and 215/ha, respectively (Table 8). The ratio described as a/b, is taken as the measure of size class distribution (Grubb *et al.*, 1963). Accordingly, the ratio of individuals with DBH between 10 & 20 cm (a) to DBH > 20 cm (b) was 1.53 for Komto Forest. This indicates that the proportion of medium-sized individuals (DBH between 10 and 20 cm) is larger than the large sized individuals (DBH $\geq$ 20 cm) but the ratio is relatively lower than the results obtained for other forests (Alata-Bolale, Menagesha Suba, Chilimo and Masha Anderacha) but larger than Dodola Forest (Table 9). The proportion of small-sized individual (DBH<10 cm) was much larger (42.82%) although the above ratio is lower (Table 8), indicating that Komto Forest is at stages of secondary regeneration. Comparisons of tree densities with DBH between 10 & 20 cm (a), DBH > 20 cm (b) and the ratio (a/b) for Komto Forest with other 10 forests in Ethiopia is given in Table 9.

Table 8: Number of individuals under different DBH classes

	No. of individuals	
DBH (cm)	**/ha**	**%**
2.5-10.0	408.02	42.82
10.1-20.0	330.00	34.61
>20.0	215.00	22.57
Total	**952.83**	**100**

Table 9: Comparisons of tree densities with DBH between 10 & 20 cm (a) and tree density with DBH > 20 cm (b) from Komto Forest with 10 other forests in Ethiopia

	Density		**Ratio**	
Forests	**(a)**	**(b)**	**a/b**	**Sources**
Alata-Bolale	365	219	1.67	Woldeyohannes Enkossa, 2008
Chilimo	638	250	2.55	Tamrat Bekele, 1993
Dindin	437	219	2.00	Simon Shibru and Girma Balcha, 2004
Dodola	521	351	1.48	Kitessa Hundara *et al.*, 2007
Donkoro	526	285	1.85	Abate Ayalew *et al*., 2006
Gura Ferda	500	263	1.90	Derje Denu, 2006
Masha Andaracha	385.7	160.5	2.40	Kumlachew Yeshtela and Taye Bekele, 2003
Menagesha Suba	484	208	2.33	Tamrat Bekele, 1993
Menna Angetu	292	139	2.10	Ermias Lulekal, 2008
Wof Washa	329	215	1.53	Tamrat Bekele, 1993
Komto	**330**	**215**	**1.53**	**Present study**

4.5.2 Size class distributions

The frequency distribution of height classes of trees and shrubs in the Komto Forest is given in Figure 6. The height class distribution of trees and shrubs in Komto Forest (Figure 5) indicated that more than 65% of the individuals had height less than 9 m (Height classes 1 and 2). Only small proportion, about 24%, reached height up to 15 m and above indicating the dominance of Forest by low stature individuals. Generally, the frequency distribution of individuals in different height classes showed an irregular pattern. The relative density was decreasing in the 5th and 7th height classes (15.1-18.0 m and 21.1-24.0 m) and increasing in the height classes 6th and 8th (18.1-21.0 and 24.1-27.0) (Figure 6). This could be attributed to high rate of regeneration but irregular recruitment which may be due to selective cuttings at different size such as size classes 5 and 7. Feyera Senbeta and Demel Teketay (2003) also stated that the dominance of shrubs and small trees in the floristic composition of the forest suggest that bigger tree species are selectively removed or exploited.

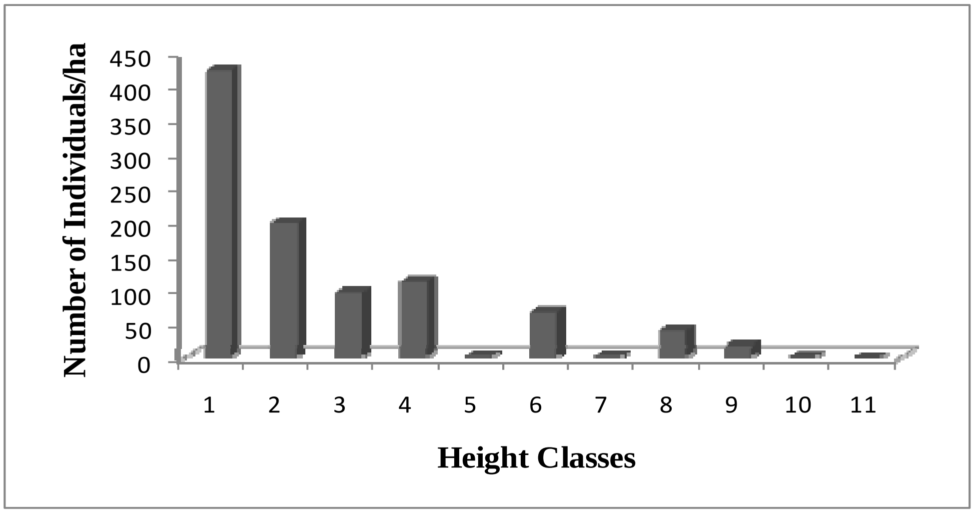

Figure 5: Height classes versus relative density/ha in Komto Forest.

Legend: 1=2.6-6.0 m, 2=6.1-9.0 m, 3=9.1-12.0 m, 4=12.1-15.0 m, 5=15.1-18.0 m, 6=18.1-21.0 m, 7=21.1-24.0 m, 8=24.1-27.0 m, 9=27.1-30.0 m and 10>30.0m.

The diameter at breast height (DBH) class distribution of the woody species is given in Figure 6. As the DBH class size increases, the number of individuals gradually decrease beginning from 548.58 stems/ha in the first class down to 12.73 stems/ha in the last DBH class. This appears to be a regular inverted J-shaped distribution of individuals in the different DBH classes.

From the figure, it is also evident that about 57% of the individuals have DBH between 2.6 cm and 12 cm (DBH class 1) and more than 77% of the individuals have DBH less than 22 cm (DBH classes 1 and 2). Only 14% of the total individuals have DBH greater than 42 cm indicating the dominance of small-sized individuals in the Forest and the Forest is in the stage of secondary regeneration. However, the frequency distribution of individuals in the different size class in Komto Forest is not uniform. The number is lower at the DBH class 3 (Figure 6). This might be due to selective cutting of individuals at specific size. For example, medium sized individuals of *Prunus africana* tree are highly hunted by the local people mainly for construction of houses (personal observation and communication with the local people).

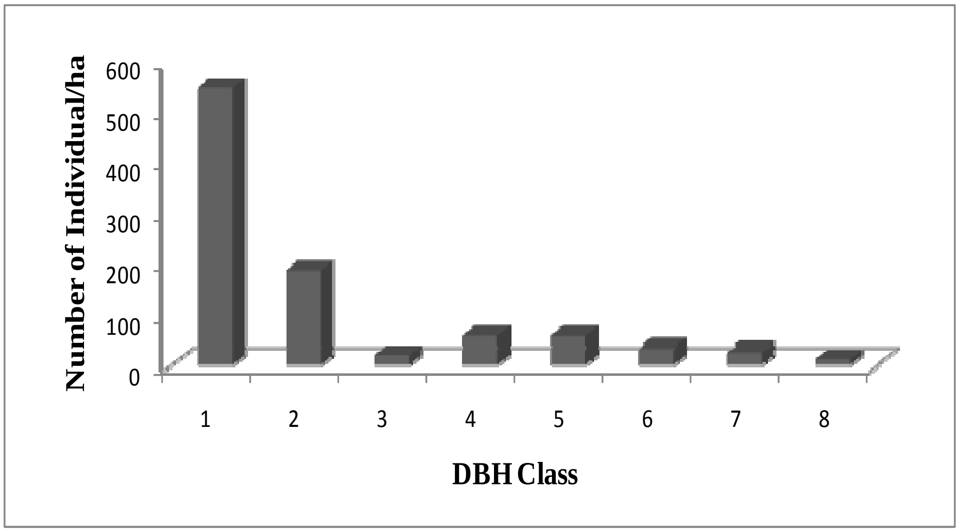

Figure 6: DBH class versus the number of individuals/ha

Legend: DBH class 1=2.6-12.0 cm, 2=12.1-22.0 cm, 3=22.1-32.0 cm, 4=32.1-42.0 cm, 5=42.1-52.0 cm, 6=52.1-62.0 cm, 7=62.1-72.0 cm and 8≥72.0 cm.

4.5.2.1 Basal area

Basal area provides a better measure of the relative importance of the species than simple stem count (Cain and Castro 1959; cited in Tamirat Bekele, 1994). Therefore, species with the largest contribution in basal area can be considered as the most important woody species in the forest. Accordingly, from the relative basal area calculation, it is indicated that *Syzygium guineense* ssp. *afromontanum, Ficus sur, Croton macrostachyus* and *Apodytes dimidiata* were the most dominant and most important species because of their higher relative density and frequency (Table 12).

Total basal area for Komto Forest was 50.72 m^2/ha, and this constitutes 0.507 % of the total ground area. A comparative contribution of the different DBH classes to the total basal area is presented in Table 10 and Figure 7. It is evident from the table that, even though about 57% of all the individuals had DBH less than 12 cm (DBH class 1), the percentage contribution of these classes to the total basal area was only 3.87%. Conversely, individuals in the DBH classes greater than 42 cm had a density of about 14% of the total, but they contributed to about 69.64% of the total basal area computed for the Forest. Similar results were also obtained in the analyses of the contribution of the different DBH classes to the basal area in different forests of Ethiopia as in Masha Anderacha Forest (Kumlachew

Yeshitila and Taye Bekele, 2003), Dodola Forest (Kitessa Hundera *et al.*, 2007), Belete Forest (Kitessa Hundera and Tsegaye Gadissa, 2008) that few large sized individuals contribute larger proportion of the total basal area. Therefore, large sized individuals have very significant importance in this forest.

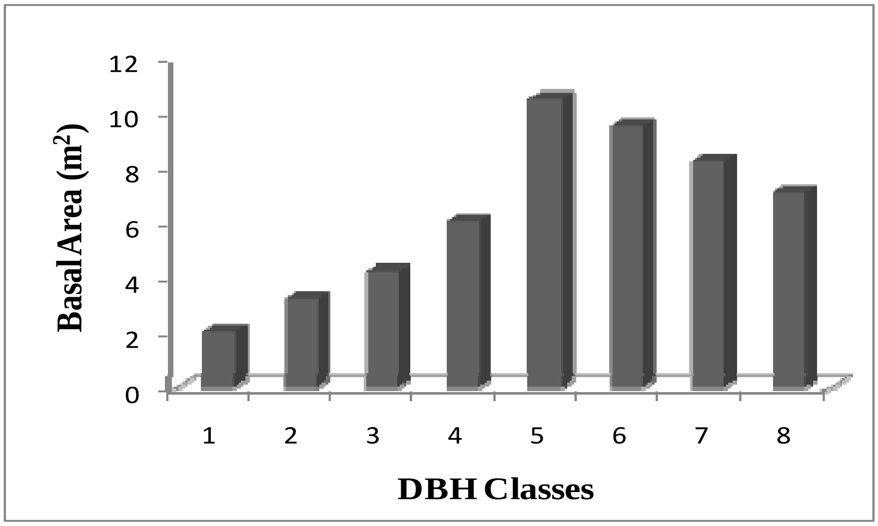

Figure 7: Basal area distribution over DBH classes of Komto Forest

Legend: DBH class 1=2.6-12.0 cm, 2=12.1-22.0 cm, 3=22.1-32.0 cm, 4=32.1-42.0 cm, 5=42.1-52.0 cm, 6=52.1-62.0 cm, 7=62.1-72.0 cm and 8≥72.0 cm.

Table 10: Contribution of different DBH classes to the total density and basal area/ha in Komto Forest

DBH Classes	Density		Basal Area	
	Number of Stem	%	m^2	%
1	548.58	57.57	1.966	3.87
2	189.15	19.85	3.2	6.31
3	21.69	2.27	4.2	8.28
4	58.98	6.19	6.03	11.89
5	58.49	6.14	10.51	20.72
6	35.38	3.71	9.51	18.75
7	27.83	2.92	8.2	16.17
8	12.73	1.34	7.1	14.00
Total	**952.83**	**99.98**	**50.716**	**99.99**

Legend: DBH class 1=2.6-12.0 cm, 2=12.1-22.0 cm, 3=22.1-32.0 cm, 4=32.1-42.0 cm, 5=42.1-52.0 cm, 6=52.1-62.0 cm, 7=62.1-72.0 cm and 8≥72.0 cm.

The total basal area calculated for Komto Forest was 50.72 m^2/ha, of which more than 21.47% (10.89 m^2/ha) was contributed by *Syzygium guineense* ssp. *afromontanum* (Table 12). The predominance of this species in the Forest was probably because of its low demand for timber and other purposes by the local people. *Syzygium guineense* ssp. *afromontanum* was also the dominant species in the Belete forest because of a similar reason (Kitessa Hundera and Tsegaye Gadissa, 2008). The basal area of Komto Forest was greater than that of Menagesha Suba and Chilimo (Tamrat Bekele, 1993) and Denkoro Forest (Abate Ayalew *et al.*, 2006). In terms of the total basal area, Komto Forest is comparable with Jibat Forest (Tamrat Bekele, 1993) and Dindin Forest (Simon Shibiru and Girma Balcha, 2004) but it has less basal area than Alata-Bolale Forest (Woldeyohannes Enkossa, 2008), Gendo Forest (Teshome Gemechu, 2009), Masha-Anderacha Forest (Kumlachew Yeshitila and Taye Bekele, 2003) and Wof-Washa Forest (Tamrat Bekele, 1993) (Figure 8).

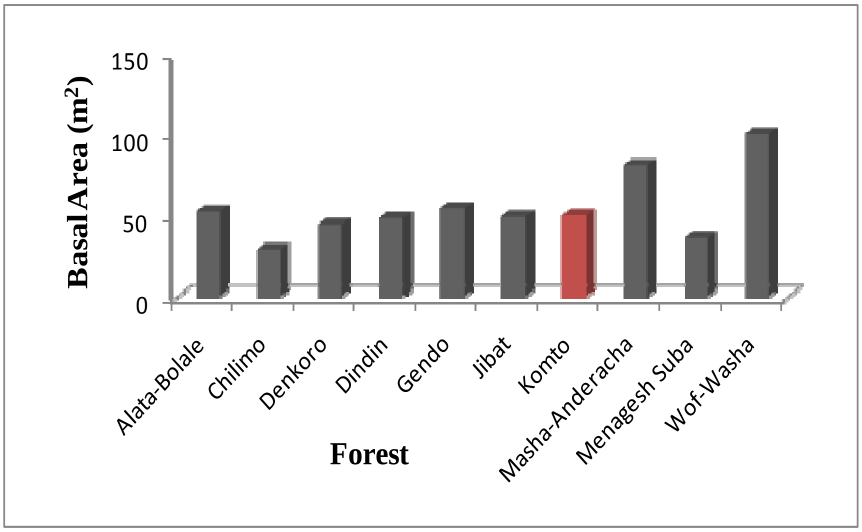

Figure 8: Basal Area (in m^2) of different forests in Ethiopia

4.5.2.2 Vertical structure

The vertical structure of the woody species occurring in the Komto Forest was analyzed using the IUFRO classification scheme (Lamprecht, 1989). The scheme classifies the storey into upper, where the tree height is greater than 2/3 of the top height; middle, where the tree height is in between 1/3 and 2/3 of the top height and the lower storey where the tree height is less than 1/3 of the top height. The top height for trees in Komto Forest was 40 m. Accordingly, the emergent tree species that occupied the upper storey in Komto Forest include *Croton macrostachyus, Prunus africana, Pouteria adolfi-friederici, Ficus sur, Schefflera abyssinica, Euphorbia ampliphylla, etc.* In addition, only few individuals attained the upper storey as the ratio of individuals to species is lower (Table 11).

The middle layer of Komto Forest was occupied by species like *Syzygium guieneense* ssp. *afromontanum, Allophylus abyssinicus, Albizia gummifera, Albizia schimperiana, Teclea nobilis, Vepris dainellii, Olea capensis* ssp. *macrocarpa, Canthium oligocarpum, Millettia ferruginea, Olea welwitschii, etc.* The lower storey was largely dominated by shrubs and small trees such as *Rytigynia neglecta, Erytrococca trichogyne, Clausena anisata, Chionanthus mildbraedii, Dombeya torrida, Flacourtia indica, Psychotria orophila*, etc.

From this it is important to note that the highest proportion of species was concentrated in the lower storey (94.44%) followed by the middle (69.44%) and upper storey (36.11%) of the vertical structure of the Komto Forest (Table 11). Similar result was also observed by

Ensermu Kelbessa and Teshome Soromessa (2008) in the comparison of the frequency distribution of species in different storey of Bonga Forest that few species attain the upper storey.

Table 11: Density, Species number and individuals to species ratios by Storey

		Stem		Species		Ratio of individuals to
Storey	**Height (m)**	**Density**	**%**	**No.**	**%**	**species**
Lower	2.5-13.33	657.07	68.96	34	94.44	19.3:1
Middle	13.33<H<26.66	277.83	29.16	28	77.77	10.0:1
Upper	>26.66	17.92	1.88	9	25.00	2.0:1

4.5.3 Importance Value Index

IVI analysis is used for setting conservation priority. Those species which receive lower IVI values need high conservation efforts while those with higher IVI values need monitoring management. The Importance Value Index (IVI) of 36 species was calculated (Table 12). This shows that *Syzygium guineense* ssp. *afromontanum, Croton macrostachyus, Ficus sur, Allophylus abyssinicus, Apodites dimidiata, Rytigynia neglecta,* and *Pouteria adolfi-friederici* were the first seven most important species with higher IVI values (Table 12).

This is mainly because of their high dominance and density which is due to their low demand by the local people for timber and other construction material. Distribution of species among different IVI classes indicated that most of the species were in the lower IVI classes (Figure 9). These above seven species contributed about 50% of the total importance values whereas the remaining woody species (80.56%) had importance value indices of about 50%. In addition, Myrtaceae, a family with single species *Syzygium guineense* ssp. *afromontanum,* is the most important family in the Forest (Table 12).

4.5.3.1 Density, Frequency and Dominance

Analysis of the relative density indicated that *Rytigynia neglecta, Syzygium guineense* ssp. *afromontanum, Pouteria adolfi-friederici* and *Croton macrostachyus* were the four most abundant species and constitute about 29.7% of the total density (Table 12). Hence, *Syzygium guineense* ssp. *afromontanum, Croton macrostachyus, Allophylus abyssinicus* and *Rytigynia neglecta* were the most frequently occurring species (Table 12).

Table 12: Importance Value Index (IVI) of the dominant tree species of Komto forest
(RF = Relative Frequency, RD = Relative Density and RDO = Relative Dominance IVI = Important Value Index)

Species	**RD**	**RDO**	**RF**	**IVI**
Syzygium guineense ssp. *afromontanum*	7.77	21.5	6.41	35.67
Croton macrostachyus	6.78	12.54	6.41	25.73
Ficus sur	4.55	16.6	3.12	24.26
Allophylus abyssinicus	5.84	4.5	6.08	16.41
Apodytes dimidiata	3.91	6.90	4.60	15.39
Rytigynia neglecta	9.31	0.22	5.75	15.28
Pouteria adolfi-friedrici	6.83	4.10	3.94	14.87
Prunus africana	2.92	6.66	2.63	12.21
Bersama abyssinica	5.30	1.30	5.43	12.01
Erytrococca trichogyne	5.49	0.20	4.44	10.13
Albizia schimperiana	1.98	4.83	2.46	9.27
Vepris dainellii	2.72	1.14	5.26	9.12
Maesa lanceolata	3.27	1.62	4.09	8.98
Teclea nobilis	2.37	0.92	5.09	8.38
Clausena anisata	4.31	0.07	3.31	7.69
Albizia gummifera	1.88	2.90	1.80	6.58
Euphorbia ampliphylla	1.63	4.02	0.82	6.47
Pittosporum viridiflorum	2.62	0.41	2.30	5.33
Maytenus undata	2.82	0.20	1.97	4.96
Dombeya torrida	1.88	0.10	2.79	4.76
Psychotria orophila	2.18	0.30	2.26	4.71
Ekebergia capensis	0.54	2.56	1.48	4.58

Species	RD	RDO	RF	IVI
Macaranga capensis	0.94	1.71	1.31	3.96
Olea welwitschii	1.98	0.26	1.48	3.72
Canthium oligocarpum	1.29	0.31	1.97	3.57
Vernonia amygdalina	1.33	0.14	1.83	3.30
Celtis africana	1.73	0.63	0.69	3.05
Chionanthus mildbraedii	1.29	0.07	1.64	2.997
Cassiporea malosana	1.23	0.08	1.64	2.95
Calpurnia aurea	0.74	0.12	1.97	2.83
Schefflera abyssinica	0.19	1.42	0.65	2.26
Olea capensis ssp. *macrocarpa*	0.69	0.08	1.31	2.08
Flacourtia indica	0.59	0.03	1.15	1.765
Millettia ferruginea	0.69	0.15	0.61	1.45
Ritchiea albersii	0.19	0.30	0.49	0.96
Hagenia abyssinca	0.15	0.43	0.33	0.91
Total	**99.93**	**99.32**	**99.51**	

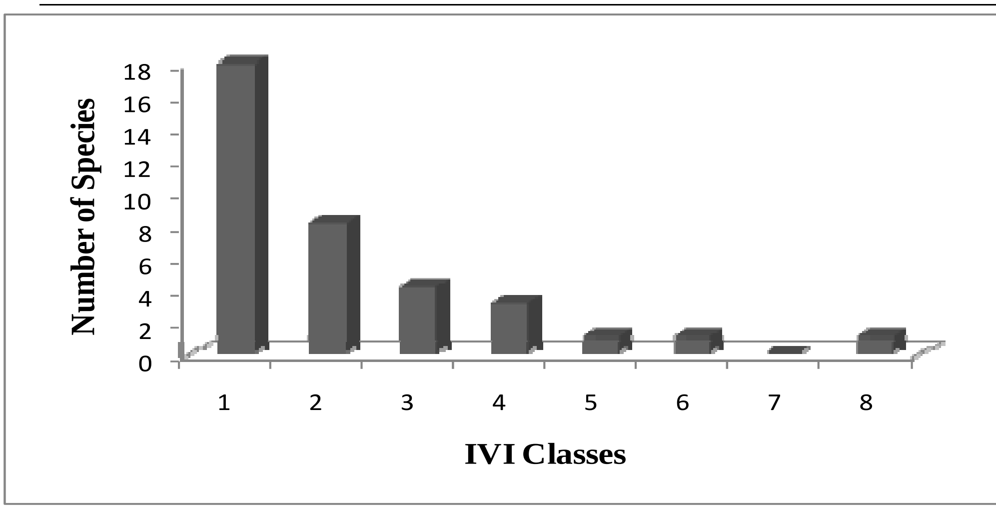

Figure 9: Distribution of IVI classes against number of species in Komto ForestIVI class (IVI classes 1=0-5, 2=5.1-10.0, 3=10.1-15.0, 4=15.1-20.0, 5=20.1-25.0, 6=25.1-30.0, 7=30.1-35.0 and 8=35.1 and above)

4.5.3.2 Dominant Species of Komto Forest

Dominant species were selected based on their rank in IVI values indicated in Table 12. Species having IVI value above 5.00 are referred to as dominant because of the relative ecological importance they played in the forest ecosystem and also their abundance in distribution, and high basal area within the forest. Accordingly, *Syzygium guineense* ssp. *afromontanum, Croton macrostachyus, Ficus sur, Allophylus abyssinicus, Apodytes dimidiata, Rytigynia neglecta, Pouteria adolfi-friederici, Prunus africana, Bersama abyssinica, Erytrococca trychogyne, Albizia schimperiana, Vepris dainellii, Maesa lanceolata, Teclea nobilis, Clausena anisata, Albizia gummifera, Euphorbia ampliphylla* and *Pittosporum viridiflorum* were identified as dominant species of the Forest.

4.5.4 Population Structure

The patterns of diameter class distribution indicate the general trends of population dynamics and recruitment processes of a given species. Analysis of the population of 36 tree species in the Forest revealed four general patterns (Figure 10). The first pattern was bell-shaped distribution formed by species with high number of individuals in the middle DBH classes (Figure 10A). Species such as *Croton macrostachyus* and *Syzygium guineense* ssp. *afromontanum* are characterized by this distribution pattern. This pattern indicates a poor reproduction and recruitment of species which may be associated with intense competition from the surrounding trees. Feyera Senbeta *et al.* (2007) and Woldeyohannes Enkossa (2008) have also reported similar justification for bell-shaped population structure. The second pattern was formed by species with positively skewed distribution (inverted J-curve). These species had the highest density in the lower DBH with gradual decrease in density towards the bigger sizes, which suggested good reproduction and healthy regeneration potential in the forest (Figure 10B). *Vepris dainellii, Teclea nobilis, Canthium oligocarpum, Bersama abyssinica, Cassipourea malosana, Maesa lanceolata, Apodites dimidiata,* etc; had inverted J-curve structure.

The third pattern (Figure 10C) was formed by species having irregular distribution over diameter classes. Some diameter classes were poorly represented indicating selective removal of specific sized individuals while other diameter classes are well represented. The following species had this type of population pattern: *Albizia schimperiana, Albizia* *gummifera*, *Allophylus abyssinicus*, *Euphorbia ampliphylla*, *Ficus sur, Macaranga capensis,* etc.

The fourth pattern was a U-shaped curve (Figure 10D) formed by species with little or no individuals in the middle DBH classes and represented only by the lower and higher DBH classes. Species with this type of population structure are *Prunus africana*, *Pouteria adolfi-friederici*, *Ekebergia capensis*, etc. The intermediate diameter classes are poorly represented may be due to selective removal of medium sized individuals. For example, many stumps of *Pouteria adolfi-friederici*, the very important timber tree species in the area, were observed in the forest, which suggest a further risk of removal of the remaining individuals.

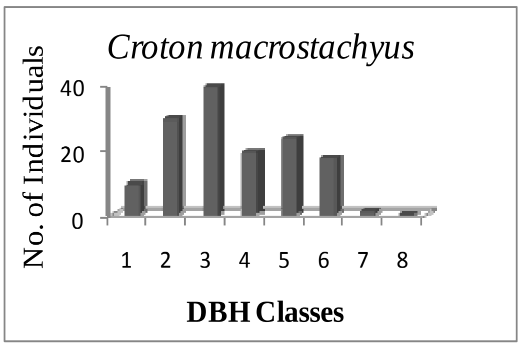

Figure 10A

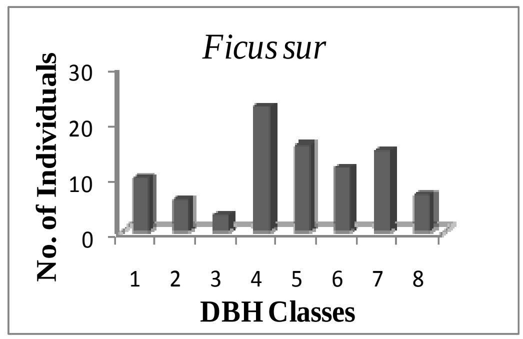

Figure 10C

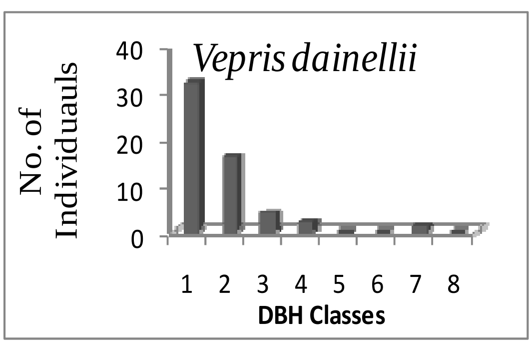

Figure 10B

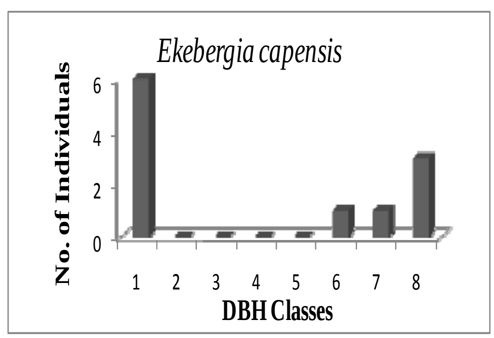

Figure 10D

Figure 10: Population structure of some selected tree specie

Legend: DBH class 1=2.6-12.0 cm, 2=12.1-22.0 cm, 3=22.1-32.0 cm, 4=32.1-42.0 cm, 5=42.1-52.0 cm, 6=52.1-62.0 cm, 7=62.1-72.0 cm and 8≥72.0 cm.

An inverted J- shaped distribution was exhibited by some tree species representing a healthy regeneration (Figure 10B). On the other hand, other distribution patterns such as bell-shaped, irregular and U-shaped (Figure 10A, C and D) were also observed. Most of the species with irregular distributions are tree species that are hunted by the local people selectively for logging, house construction, firewood and charcoal production or over grazing which affects the seedlings under the mother tree. For example, *Prunus africana* at its medium size is highly needed for construction (personal communication with the local people and personal observation). The complete absence of individuals in some diameter classes indicates that the regeneration of species was hampered during one or several phases of their life cycle. These might be caused by trampling by livestock, selective cutting for construction, timber or firewood purposes.

4.5.5 Phytogeographical comparison

According to the findings of this study, Komto Forest is one of the diverse forests in Ethiopia. Many authors have studied the dry afromontane forest and moist afromontane forests in the country. Although the direct comparison of the species diversity with other forests is not feasible due to differences in size of forests, survey methods, and objective of the study (Tadesse Woldemariam, 2003), the over all species richness of the forest can give more or less a general impression of their diversity and phytogeographical similarity. In this regard, Komto Forest was compared with other 10 afromontane forests in the country to know the similarity of species in the forests and indicate to which forest type Komto Forest is related. Table 13 gives the findings of this comparison. These forests were: Alata-Bolale, Belete, Gendo (Gura Tirigni), Harenna, Jibat, Jima, Masha Anderacha, Menagesha-Suba, Southwestern Ethiopian forest, and Yayu. Ninty nine woody species (trees, shrubs and lianas) were used for similarity comparisons. The similarity index used for this comparison was Sorensen’s Similarity index (as indicated under 3.2.4.2 Diversity and Similarity section).

Accordingly, Komto Forest shared significant number of species with Alata Bolale, Gendo (Gura Tirigni), Yayu, Jima, Masha Anderacha and Southwestern Ethiopian forest in decreasing order. The high similarity observed among these forests could be due to similar altitudinal ranges and climatic conditions. Komto Forest shared more species in common with moist montane forests indicating that it is highly related to the Moist Afromontane forests in the country.

Lower number of species was shared between Komto and Belete, Harenna, Menagesha Suba and Jibat forests. Dissimilarities between these forests may arise from their location (far apart from Komto Forest), altitudinal differences and climatic conditions.

Table 13: Phytogeographical Comparison of Komto forest with other 10 forests in Ethiopia (Bold values indicate the highest similarity).

No.	Forest	Altitudinal range (m a.s.l.)	No. of Spp. in compariso	a	b	c	Sc (%)	References
1	Menagesha	2300-3000	48	29	70	19	39	Tamrat Bekele, 1993
2	Jibat	2000-2950	48	29	70	19	39	Tamrat Bekele, 1993
3	Harenna	2200-3300	85	40	59	45	43	Lissanework Nigatu,
4	Belete	1850-2250	79	44	55	35	**49**	Kitessa Hundera and Tsegaye Gadissa, 2008
5	Masha-Anderacha	1250-2700	107	54	45	53	**52**	Kumlachew Yeshitila and Taye Bekele, 2003
6	Southwestern Ethiopian forest	1050-2600	100	52	47	48	**52**	Kumlachew Yeshitila, 1997
7	Jima	2166-2470	90	51	48	39	**54**	Fufa Kenea, 2008
8	Yayu	1200-2000	92	56	43	36	**58**	Tadesse Woldemariam, 2003
9	Gendo	2183-2300	90	59	40	31	**60**	Teshome Gemechu,
10	Alata-Bolale	2061-2360	98	66	33	32	**67**	Woldeyohannes Enkossa, 2008

The most characteristic tree species of moist Afromontane forest are found in this study area. These include *Pouteria adolfi-friederici*, *Prunus africana*, *Syzygium guinneense* ssp. *afromontanum*, *Vepris dainellii*, *Teclea nobilis* and other species which were also reported in. The altitudinal range of Komto forest is within the altitudinal range of the Moist Aformontane forests, which is from 1500 - 2500 m.a.s.l. (White, 1983; Friis, 1992; Sebsebe Demissew *et al*., 2004). Hence, Komto forest belongs to Moist Montane Forest Vegetation Type.

4.5.6 Regeneration Status of Komto Forest

The composition and density of seedlings and saplings of selected tree species in Komto Forest were included in this study. The total seedling, sapling and mature woody tree densities of 36 selected tree species were about 1888, 897 and 952.83 individuals per hectare respectively (Appendix III). The composition, distribution and density of seedlings and saplings are indicators of the future regeneration status of any forest. Based on the results of this study, 7 species (19.44%) of the total were not represented by both seedling and sapling stages. These species were *Hagenia abyssinica, Ritchiea albersii, Schefflera abyssinica, Macaranga capensis, Ekebergia capensis, Vernonia amygdalina* and *Flacourtia indica*. In addition, only few mature individuals were recorded for these species during data collection (Appendix III). On the other hand, 5 species (13.88%) of the total were not represented by sapling stage in Komto Forest. These species include *Calpurnia aurea, Euphorbia ampliphylla, Millettia ferruginea, Olea capensis* ssp. *macrocarpa,* and *Olea welwitschii*.

Possible reasons for insufficient seedling and sapling for the above tree species in the forest might be seed predation, grazing and browsing, lack of safe site for seed recruitment, nature of seeds of certain trees which seek dormancy period, litter accumulation, pathogens, species specificity, and moisture stress or probably they might have other alternative adaptations for propagation and reproduction rather than seed germination. Similar findings were also reported by Dereje Denu (2007), Simon Shibiru and Girma Balcha (2004), and Teshome Gemechu (2009).

Vepris dainellii, Teclea nobilis, Croton macrostachyus, Apodytes dimidiata and *Allophylus abyssinicus* were represented by both seedling and sapling stages hence, have relatively higher regeneration status. Others such as *Hagenia abyssinica, Ritchiea albersii, Schefflera abyssinica, Macaranga capensis, Ekebergia capensis, Vernonia amygdalina* and *Flacourtia indica* and those without sapling stage, however, have lower regeneration status which may suggest that these species are either under threat of local extinction or may prefer coppices or sprouts as the strategy of survival.

Based on these results, tree species of Komto Forest are grouped into 3 priority classes for conservation. These are class 1: those species with no seedling and sapling, Class 2: those with seedlings but no sapling, and Class 3: those with both seedlings and saplings $\geq$ 1 individual/ha (Table 14). The first and second priority classes, therefore, need due attention in order to save them from local extinction.

Table 14: Species conservation Priority Classes

Priority Class 1	**Priority Class 2**	**Priority Class 3**
Hagenia abyssinica	*Millettia ferruginia*	*Vepris dainellii*
Ritchiea albersi	*Olea welwitschii*	*Teclea nobilis*
Schefflera abyssinica	*Olea capensis* ssp. *macrocarpa*	*Croton macrostachyus*
Macaranga cpensis	*Calpurnia aurea*	*Apodytes dimidiata*
Ekebergia capensis	*Euphorbia ampliphylla*	*Allophylus abyssinicus*
Vernonia amygdalina		*Pouteria adolfi-friederici*
Flacourtia indica		*Prunus africana*
		Pittosporum viridiflorum
		Bersama abyssinca
		Albizia schimperiana
		Albizia gummifera
		Rytigynia neglecta
		Syzygium guineense ssp. *afromontanum*

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The study has resulted in the documentation of 180 vascular plant species representing 151 genera and 66 families. Fabaceae and Asteracae were found to be the most dominant families followed by Lamiaceae, Poaceae, and Malvaceae. Euphorbiaceae, Acanthaceae and Celastaceae families had also significant contribution to the overall species composition of the Forest. Of the total species recorded, 31 were new records from Wollega (WG) floristic region in the flora of Ethiopia and Eritrea. Komto Forest was also important reservoir of endemic plants as about 18 endemic plant species some of which are in the IUCN Red Data List were identified. Hence, Komto Forest could serve the purpose of biodiversity conservation.

The vegetation of Komto Forest was grouped into four plant community types. These communities were arranged along different altitudinal range. Plant community 1 exhibited the highest species richness (89) while the highest diversity was observed for community type four. Community type three was known with the least species richness and diversity while community type two was with intermediate species richness and diversity. The variation in species composition and diversity among communities could be associated to different factors, such as altitude, anthropogenic impacts, soil properties, slope and aspect.

Structural description of the forest indicated the predominance of small sized individuals which asserts that Komto Forest is at a stage of secondary regeneration. In addition, the density of woody species (trees, shrubs and lianas) in Komto Forest decreases with increasing DBH and height classes (high density of trees and shrubs in the lower classes) implying good recruitment. The total basal are for Komto Forest was 50.72 m^2/ha, but most of the basal area was contributed by few large sized individuals (basal area increases with increasing DBH). Analysis of population structure of most common species of trees and shrubs revealed different patterns of population structure, indicating a high variation among species population dynamics within the forest. Accordingly, four population patterns have been observed (bell shaped, inverted J-shaped, irregular and U-shaped). Phytogeographical comparison indicated that Komto Forest had the highest similarity with Moist Montane forests than other vegetation types implying Komto Forest is one of the Afomontane Rainforests of the country.

Analysis of regeneration of some selected woody species revealed that a significant number of tree species (7) are without seedling and sapling stage in the forest, some (5) tree species are without sapling stage while others are represented by all stages (seedling, sapling and mature). Based on this result the woody species of Komto Forest are grouped in to three priority classes for conservation.

5.2 Recommendation

Komto Forest afford a great economic and social value for the rural communities living around the forest, as a source of both timber and non-timber products. Therefore, to ease the present human influence on the natural forest, and for a future management of the forest on a sustainable basis, the following recommendations are forwarded:

1. Participatory forest management programs should be introduced and implemented so that local communities assume responsibility for the management and conservation of the forest and become beneficieries of the economic payback derived from this activity.
2. The species in the first and second priority classes for conservation should be given appropriate attention and should be conserved in-situ (in their natural habitat) through the collaboration of local communities and the District Agriculture and Rural Development Office and other interested individuals and stakeholders; and further investigation should be carried out to note the actual reasons for the absence of regeneration.
3. Creating public awareness, through extension programs, on the multiple uses of forest resources and ecosystems is essential to safeguard the biodiversity of the Forest.
4. Carryout further investigation on the patterns of ecosystem functioning, the soil seed banks, germination performance of seeds, establishment of seedlings and studies on the role of gap dynamics for suggested species.
5. The management strategy should focus on multiple-use conservation approach. For example, undesturbed areas of the forest can be designated for strict conservation so

that they may act as repositories of biodiversity and possibly as a source of forest genetic resources while the peripheral areas could be utilized on a sustainable basis.

6. To promote the sustainable use of the forest and its products, ethnobotanical studies and exploration of indigenous knowledge on the diverse uses of plants should be carried out.
7. The planning and management of the Forest should be assisted by research findings, such as detailed ecological studies in relation to various environmental factors such as soil type and properties. Therefore, more basic and applied researches should be promoted

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APPENDICES

Appendix 1: Sample Plots together with the corresponding altitude and location

Transect	Plot (Quadrat)	Altitude (m.asl)	Latitude	Longitude
1	1	2275	09^{0}05.661' N	036^{0}37.176' E
	2	2289	09^{0}05.384’N	036^{0}37.134’E
	3	2329	09^{0}05.393’N	036^{0}37.172’E
	4	2357	09^{0}05.403’N	036^{0}37.204’E
	5	2370	09^{0}05.378’N	036^{0}37.211’E
2	6	2271	09^{0}05.282’N	036^{0}37.123’E
	7	2293	09^{0}05.280’N	036^{0}37.147’E
	8	2317	09^{0}05.324’N	036^{0}37.172’E
	9	2332	09^{0}05.339’N	036^{0}37.189’E
	10	2380	09^{0}05.331’N	036^{0}37.203’E
3	11	2167	09^{0}05.172’N	036^{0}37.102’E
	12	2184	09^{0}05.215’N	036^{0}37.131’E
	13	2285	09^{0}05.252’N	036^{0}37.167’E
	14	2299	09^{0}05.262’N	036^{0}37.204’E
	15	2345	09^{0}05.286’N	036^{0}37.222’E
	16	2370	09^{0}05.299’N	036^{0}37.239’E
	17	2395	09^{0}05.323’N	036^{0}37.244’E
4	18	2225	09^{0}05.345' N	036^{0}37.443' E
	19	2240	09^{0}05.396' N	036^{0}37.480' E
	20	2288	09^{0}05.458' N	036^{0}37.465' E
	21	2362	09^{0}05.508' N	036^{0}37.490' E
	22	2370	09^{0}05.535’N	036^{0}37.485’E
	23	2375	09^{0}05.566' N	036^{0}37.478' E

Transect	Plot (Quadrat)	Altitude (m.asl)	Latitude	Longitude
	24	2395	$09^0$05.591' N	$036^0$37.480' E
5	25	2206	$09^0$05.315' N	$036^0$37.596' E
	26	2233	$09^0$05.366' N	$036^0$37.576' E
	27	2256	$09^0$05.434' N	$036^0$37.563' E
	28	2285	$09^0$05.485' N	$036^0$37.559' E
	29	2313	$09^0$05.508' N	$036^0$37.553' E
	30	2341	$09^0$05.526' N	$036^0$37.537' E
	31	2375	$09^0$05.549' N	$036^0$37.516' E
6	32	2190	$09^0$05.343' N	$036^0$37.691' E
	33	2230	$09^0$05.393' N	$036^0$37.672' E
	34	2255	$09^0$05.436' N	$036^0$37.642' E
	35	2277	$09^0$05.487' N	$036^0$37.641' E
	36	2300	$09^0$05.529' N	$036^0$37.644' E
	37	2325	$09^0$05.554' N	$036^0$37.619' E
	38	2350	$09^0$05.570' N	$036^0$37.585' E
	39	2382	$09^0$05.590' N	$036^0$37.550' E
7	40	2186	$09^0$05.388' N	$036^0$37.750' E
	41	2225	$09^0$05.447' N	$036^0$37.733' E
	42	2250	$09^0$05.507' N	$036^0$37.730' E
	43	2275	$09^0$05.540' N	$036^0$37.698' E
	44	2305	$09^0$05.567' N	$036^0$37.671' E
	45	2325	$09^0$05.593' N	$036^0$37.631' E
	46	2340	$09^0$05.622' N	$036^0$37.614' E
8	47	2180	$09^0$05.391' N	$036^0$37.942' E
	48	2218	$09^0$05.445' N	$036^0$37.904' E

Transect	Plot (Quadrat)	Altitude (m.asl)	Latitude	Longitude
	49	2251	$09^0$05.531' N	$036^0$37.867' E
	50	2280	$09^0$05.585' N	$036^0$37.800' E
	51	2285	$09^0$05.608' N	$036^0$37.759' E
	52	2315	$09^0$05.649' N	$036^0$37.702' E
9	53	2482	$09^0$05.827' N	$036^0$37.598' E

Appendix 2: List of plant species collected from Komto Forest. Key: T=Tree, SH=Shrub, H=Herb, Cl=Climber and E=Epiphyte (Hemi parasite) and G=Grass & Sedge

Item No.	Scientific Name	Family	Vernacular Name (Afaan Oromoo)	Coll. No.	Habit
1	*Abutilon figarianum* Webb.	Malvaceae		FG 0121	SH
2	*Abutilon longicuspe* Hochest. ex A.Rich.	Malvaceae	Hincinnii adii	FG 0061	SH
3	*Abutilon martinianum* (Jacq.) Medic.	Malvaceae	Qaqaroo	FG 0154	SH
4	*Acalypha marissima* M.Gilbert	Euphorbiaceae		FG 0062	H
5	*Acalypha ornata* A.Rich.	Euphorbiaceae	Gurgubbee Qamalee	FG 0109	SH
6	*Acalypha psilostachya* Hochst.	Euphorbiaceae		FG 0014	H
7	*Acanthus eminens* C.B.Clarke	Acanthaceae	Kosorruu	FG 0013	SH
8	*Achyranthes aspera* L.	Amaranthaceae	Samaxxee	FG 0084	H
9	*Achyrospermum schimperi* (Hochst.ex Briq.) Perkins	Lamiaceae		FG 0010	H
10	*Adiantum poiretii* Wikstr.	Adiantaceae		FG 0101	Fern
11	*Albizia gummifera* (J.F.Gmel.) C.A.Sim.	Fabaceae	Hambabbeessa	FG 0072	T
12	*Albizia schimperiana* Oliv.	Fabaceae	Muka arbaa	FG 0162	T
13	*Alectra sessiliflora* (Vahl) Kuntze	Scrophulariaceae		FG 0211	SH
14	*Allophylus abyssinicus* (Hochst.) Radlkofer	Sapindaceae	Malqaqqoo	FG 0043	T
15	*Andropogon abyssinicus* Fresen.	Poaceae	Baallammii	FG 0201	G
16	*Apodytes dimidiata* E.Mey.ex Arn	Icancinaceae	Wandabiyoo	FG 0049	T
17	*Arthropteris monocarpa* (Cordem.) C.Chr.	Oleandraceae		FG 0024	Fern
18	*Asparagus africanus* Lam.	Asparagaceae	Sariitii	FG 0053	Cl
19	*Asplenium anisophyllum* Kunth	Aspleniaceae		FG 0166	Fern
20	*Pteridium aquilinum* (L.) Kuhn	Athriaceae	Trimmii	FG 0070	Fern
21	*Bartsia trixago* L.	Scrophulariaceae		FG 0168	H
22	*Bersama abyssinica* Fresen.	Melianthaceae	Loshiisaa/Araarsaa	FG 0006	T
23	*Bidens ghedoensis* Mesfin	Asteraceae	Keelloo	FG 0123	H
24	*Bidens* pilosa L.	Asteraceae	Maxxannee	FG 0112	H
25	*Bothrocline schimperi* Oliv. & Heirn ex Benth.	Asteraceae		FG 0134	H
26	*Brucea antidysenterica* J.F.Mill.	Simaroubaceae	Qomonyoo	FG 0019	SH
27	*Budleja polystchya* Fresen.	Loganiaceae	Hamfaaree	FG 0156	SH
28	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	Ceekaa	FG 0050	SH
29	*Canthium oligocarpum* Hiern	Rubiaceae	Mixoo qeerramsaa	FG 0021	T
30	*Carex spicato-paniculata* Bak.ex C.B.Clarke	Cyperaceae		FG 0142	G
31	*Cassipourea malosana* (Baker) Alston	Rhizophoraceae	Xiilloo	FG 0052	T

Item No.	Scientific Name	Family	Vernacular Name (Afaan Oromoo)	Coll. No.	Habit
32	*Celtis africana* Burm.f.	Ulmaceae	Cayii	FG 0129	T
33	*Ceropegia sobolifera* N.E.Br.	Asclepiadaceae		FG 0071	Cl
34	*Chionanthus mildbraedii* (Gilg. & Schellenb.) Stearn	Oleaceae	Karra waayyuu	FG 0077	T
35	*Clausena anisata* (Willd.) Benth.	Rutaceae	Ulumaayii	FG 0030	SH
36	*Clematis simensis* Fresen.	Ranunculaceae	Hidda fiitii	FG 0079	Cl
37	*Clerodendrum myricoides* (Hochst.) Vatke	Lamiaceae		FG 0181	SH
38	*Combretum paniculatum* Vent.	Combretaceae	Hidda Baggee	FG 0149	Cl
39	*Commelina benghalensis* L.	Commelinaceae	Gorora Fardaa	FG 0193	H
40	*Conium maculatum* L.	Apiaceae		FG 0182	H
41	*Conyza schimperi* Sch.Bip.ex A.Rich.	Asteraceae	Harataa harree	FG 0164	H
42	*Crassocephalum macropappum* (Sch.Bip.ex A.Rich.) S.Moore	Asteraceae		FG 0125	H
43	*Crassocephalum rubens* (Jess.ex Jacq.) S.Moore	Asteraceae		FG 0120	H
44	*Crepis foetida* L.	Asteraceae		FG 0195	H
45	*Crotalaria rosenii* (Pax) Milne-Redh ex Polhill	Fabaceae		FG 0107	SH
46	*Crotalria milbraedii* Bak.f.	Fabaceae	Atarii waraabessaa	FG 0146	SH
47	*Croton macrostachyus* Del.	Euphorbiaceae	Bakkanniisa	FG 0001	T
48	*Cucumis ficifolius* A.Rich.	Cucurbitaceae	Faca'aa	FG 0148	H
49	*Cuscuta kilimanjari* Oliv.	Cuscutaceae	Konchii	FG 0085	Cl
50	*Cyathula uncinulata* (Schrad.) Schinz.	Amaranthaceae	Maxxannee	FG 0068	H
51	*Cynodon dactylon* (L.) Pers.	Poaceae	Coqorsa	FG 0214	G
52	*Cynoglossum amplifolium* Hochst.ex A.DC.	Boraginaceae		FG 0065	H
53	*Cyperus distans* L.f.	Cyperaceae	Qunnii/Daggoo	FG 0108	G
54	*Cyphostemma adenocaule* (Steud .ex A.Rich.) Descoings ex Wild & Drummond	Vitaceae	Hidda Reeffaa	FG 0047	Cl
55	*Dalbergia lactea* Vatke	Fabaceae	Ajjagnoo	FG 0179	SH
56	*Desmodium repandum* (Vahl) DC.	Fabaceae		FG 0074	H
57	*Digitaria velutina* (Forssk) P.Beauv.	Poaceae	Gosa margaa	FG 0015	G
58	*Dombeya torrida* (J.F.Gmel.) P. Bamps	Sterculiaceae	Daannisa	FG 0003	T
59	*Dracaena afromontana* Mildbr.	Dracaenaceae	Afarfattuu	FG 0082	SH
60	*Dracaena steudneri* Engl.	Dracaenaceae	Warqee Qamalee guddaa	FG 0190	T
61	*Dregea schimperi* (Decne.) Bullock	Asclepiadaceae	Hidda goorri'saa	FG 0171	Cl

Item No.	Scientific Name	Family	Vernacular Name (Afaan Oromoo)	Coll. No.	Habit
62	*Drymaria cordata* (L.) Schultes	Carryophylaceae		FG 0040	H
63	*Drynaria volkensii* Hieron	Polypodiaceae	Baala balleessaa	FG 0022	Fern
64	*Dryopteris inaequalis* (Schlechtend.) Kunth	Dryopteridaceae		FG 0133	Fern
65	*Echinops longisetus* A.Rich.	Asteraceae	Qoraattii Harree	FG 0177	H
66	*Ekebergia capensis* Sparrm.	Meliaceae	Somboo	FG 0185	T
67	*Embelia schmperi* Vatke	Myrsinaceae	Haanquu	FG 0090	SH
68	*Ensete ventricosum* (Welw.) Cheesman	Musaceae	Warqee	FG 0115	H
69	*Eragostis chalarothyrsos* C.E.Hub.	Poaceae		FG 0212	G
70	*Eriosema scioanum* Avetta	Fabaceae	Gurra Hantuutaa	FG 0018	Cl
71	*Erythrina brucei* Schweinf.	Fabaceae	Waleensuu	FG 0207	T
72	*Erythrococca trichogyne* (Muel.Arg.) Prain	Euphorbiaceae	Caakkoo	FG 0027	T
73	*Euphorbia ampliphylla* Pax	Euphorbiaceae	Adaamii	FG 0098	T
74	*Ficus ovata* Vahl	Moraceae	Qilimxoo	FG 0200	T
75	*Ficus sur* Forssk.	Moraceae	Harbuu	FG 0127	T
76	*Flacourtia indica* (Burm.f) Merr.	Flacourtiaceae	Akuukkuu	FG 0078	T
77	*Galiniera saxifrag* (Hochst.) Bridson	Rubiaceae		FG 0136	T
78	*Girardinia bullosa* Wedd.	Urticaceae	Doobbii	FG 0203	H
79	*Girardinia diversifolia* (Link) Friis	Urticaceae	Gurgubbee	FG 0131	H
80	*Gouania longispicata* Engl.	Rhamnaceae		FG 0192	Cl
81	*Grewia ferruginea* Hochst. ex A.Rich.	Tliaceae	Dhoqonuu	FG 0143	SH
82	*Guizotia scabra* (Vis.) Chiov.	Asteraceae	Cuqii/Tuufoo	FG 0208	H
83	*Guizotia schimperi* Sch.Bip.ex Walp.	Asteraceae		FG 0199	H
84	*Hagenia abyssinica* (Bruce) J.F.Gmel.	Rosaceae	Heexoo	FG 0176	T
85	*Helinus mystacinus* (Ait.) E. Mey. ex Steud.	Rhamnaceae		FG 0147	H
86	*Hibiscus calyphyllus* Cav.	Malvaceae	Hincinnii gurraattii	FG 0080	H
87	*Hibiscus macranthus* Hochest.ex A.Rich	Malvaceae	Hincinnii Qarancaa	FG 0128	SH
88	*Hippocratea africana* (Willd.) Loes.	Celastraceae	Hidda Xiyoo	FG 0094	Cl
89	*Hippocratea goetzei* Loes.	Celastraceae	Hidda gafarsaa	FG 0051	Cl
90	*Hyparrhenia hirta* (L.) Stapf.	Poaceae	Citaa	FG 0213	G
91	*Hypoestes forskaolii* (Vahl) R.Br.	Acanthaceae	Darguu	FG 0009	H

Item No.	Scientific Name	Family	Vernacular Name (Afaan Oromoo)	Coll. No.	Habit
92	*Impatiens hochstetteri* Webb.	Balsaminaceae		FG 0064	H
93	*Impatiens tinctoria* A.Rich. ssp. *abyssinica* (Hook.f.) Grey Wilson				
94	*Indigofera arrecta* A.Rich.	Fabaceae	Heennaa	FG 0126	T
95	*Isodon schimperi* (Vatke) J.K.Morton	Lamiaceae		FG 0067	H
96	*Isoglossa somalensis* Lindau	Acanthaceae		FG 0140	H
97	*Jasminum abyssinicum* Hochst. ex DC.	Oleaceae	Hidda Ichilbee	FG 0033	Cl
98	*Justicia diclipteroides* Lindau ssp. *aethiopica* Hedren	Acanthaceae		FG 0116	H
99	*Justicia schimperiana* (Hochst. ex Nees) T. Anders.	Acanthaceae	Dhummuugaa	FG 0017	SH
100	*Kalanchoe densiflora* Rolfe	Crasulaceae	Bosoqqee	FG 0153	H
101	*Kosteletzekya adoensis* (Hochest.ex A.Rich.) Mast.	Malvaceae	Hincinnii	FG 0210	SH
102	*Lagenaria abyssinica* (Hook. f.) C.Jeffrey	Cucurbitaceae	Buqqee Seexanaa	FG 0087	Cl
103	*Landolphia buchananii* (Hall.f.) Stapf.	Apocynaceae	Hidda geeboo	FG 0091	Cl
104	*Lepidotrichila volkensii (Gurke) Leroy*	Meliaceae		FG 0060	T
105	*Leptadenia arborea* (Forssk.) Decne.	Asclepiadaceae		FG 0046	Cl
106	*Leucas martinicensis* (Jacq.) R.Br.	Lamiaceae	Fidoo	FG 0175	H
107	*Lippia adoensis* Hchest. ex Walp.	Verbenaceae	Kusaayee	FG 0160	SH
108	*Macaranga capensis* (Baill.) Sim.	Euphorbiaceae	Doggomaa	FG 0135	T
109	*Maesa lanceolata* Forssk.	Myrsinaceae	Abbayyii	FG 0004	T
110	*Maytenus addat* (Loes.) Sebsebe	Celastraceae	Kombosha	FG 0113	T
111	*Maytenus gracilipes* (Welw.ex Oliv.) Exell ssp.*arguta* (Loes.) Sebsebe	Celastraceae	Hacaacii	FG 0117	SH
112	*Maytenus obscura* (A.Rich.) Cufod	Celastraceae	Kombosha	FG 0088	T
113	*Maytenus undata* (Thumb.) Blakelock	Celastraceae	Ilikkee	FG 0026	T
114	*Millettia ferruginia* ssp *.ferruginia* (Hochst.) Bak.	Fabaceae	Sootalloo	FG 0086	T
115	*Mimulopsis solmsii* Schweinf.	Acanthaceae		FG 0048	H
116	*Momordica foetida* Schumach.	Cucurbitaceae	Qorii simbiraa	FG 0100	Cl
117	*Nesphostylis holosericeae* (Bak.) Verdc.	Fabaceae		FG0138	Cl
118	*Nuxia congesta* R.Br.ex Fresen.	Loganiaceae	Naforoo	FG 0188	SH
119	*Ocimum lamiifolium* Hochst.ex Benth.	Lamiaceae	Hancabbii	FG 0096	SH
120	*Olea capensis* L. ssp *macrocarpa* (C.A.Wright.) Verdc.	Oleaceae	Gagamaa	FG 0076	T
121	*Olea welwitschii* (Knobl.) Gilg & Schellenb.	Oleaceae	Gajjaa	FG 0097	T

Item No.	Scientific Name	Family	Vernacular Name (Afaan Oromoo)	Coll. No.	Habit
122	*Oreoscse africana* Hook f.	Cucurbitaceae		FG 0069	Cl
123	*Orobanche minor* Smith	Orobanchaceae		FG 0209	H
124	*Panicum hochstetteri* Steud.	Poaceae	Marga Gogorrii	FG 0132	G
125	*Panicum nervatum* (Franch.) Stapf.	Poaceae		FG 0141	G
126	*Pavonia kilimandscharia* Gurke	Malvaceae		FG 0111	SH
127	*Pennisetum thumbergi* Kunth.	Poaceae	Migira saree	FG 0183	G
128	*Periploca linearifolia* Quart-Dill. & A.Rich.	Asclepiadaceae	Hidda aannolee	FG 0105	Cl
129	*Phragamanthera macrosolen* (A.Rich.) M.Gilbert	Loranthaceae	Dheertuu	FG 0081	E
130	*Physalis peruviana* L.	Solanaceae		FG 0169	SH
131	*Phytolacca dodecandra* L'Herit	Phytolaccaceae	Handoodee	FG 0180	Cl
132	*Pittosporum viridiflorum* Sims.	Pittosporaceae	Qassammee	FG 0045	T
133	*Plectranthus punctatus* L'Heirt	Lamiaceae	Siqaaqimee	FG 0186	H
134	*Polygonum nepalensis* (Meisn)Miyabe	Polygonaceae		FG 0011	H
135	*Pouteria adolfi-friederici* Rob. & Gilg	Sapotaceae	Sooqee	FG 0054	T
136	*Premna schimperi* Engl.	Lamiaceae	Urgeessaa	FG 0089	SH
137	*Prunus africana* (Hook.f.) Kalkm	Rosaceae	Hoomii	FG 0198	T
138	*Psychotria orophila* Petit	Rubiaceae		FG 0083	T
139	*Pteris catoptera* Cunz.	Pteridaceae		FG 0073	Fern
140	*Pterolobium stellatum* (Forssk.) Brenan	Fabaceae	Harangamaa	FG 0155	SH
141	*Pycnostachys meyeri* Gurke	Lamiaceae	Mata bokkee	FG 0173	H
142	*Rhamnus prinoides* L'Herit	Rhamnaceae	Geeshoo	FG 0194	SH
143	*Rhus glutinosa* Hochst.	Anacardiaceae	Xaaxessaa	FG 0157	T
144	*Ritchiea albersii* Gilg	Capparidaceae		FG 0020	T
145	*Rubus apetalus* Poir.	Rosaceae	Goraa arbaa	FG 0118	SH
146	*Rubus steudneri* Schweinf.	Rosaceae	Goraa	FG 0066	SH
147	*Rumex abyssinicus* Jacq.	Polygonaceae	Dhangaggoo	FG 0184	H
148	*Rytigynia neglecta* (Heirn) Robyns.	Rubiaceae	Mixoo	FG 0032	SH

Item No.	Scientific Name	Family	Vernacular Name (Afaan Oromoo)	Coll. No.	Habit
149	*Satureja paradoxa* (Vatke) Engl.	Lamiaceae	Kefoo sa'aa	FG 0144	H
150	*Schefflera abyssinica* (Hochst.ex A.Rich.) Harms	Araliaceae	Gatamaa	FG 0095	T
151	*Senna petersiana* (Bolle) Lock	Fabaceae	Raamsoo	FG 0151	SH
152	*Setaria megaphylla* (Steud.) Th.Dur. & Schinz.	Poaceae	Jajjaba/Baballii	FG 0106	G
153	*Sida rhombifolia* L.	Malvaceae		FG 0204	SH
154	*Sida schimperiana* Hochst ex A.Rich.	Malvaceae	Kottee harree	FG 0028	SH
155	*Solanecio gigas* (Vatke) C.Jeffrey	Asteraceae	Jilma Jaldeessaa	FG 0063	SH
156	*Solanum anguivi* Lam.	Solanaceae	Hiddii saree	FG 0058	SH
157	*Solanum incanum* L.	Solanaceae	Hiddii loonii	FG 0187	SH
158	*Solanum marginatum* L.	Solanaceae	Hiddii hongorcaa	FG 0202	SH
159	*Solenostemon autranii* (Briq.) J.K.Moore	Lamiaceae	Ajaayee	FG 0110	H
160	*Sparmannia ricinocarpa* (Eckel. & Zeyh.) O.Ktze.	Tliaceae		FG 0197	SH
161	*Sphaeranthus suaveolens* (Forssk.) DC.	Asteraceae		FG 0124	H
162	*Syzygium guineense* (Willd.) DC. ssp. *afromontanum* F.White	Myrtaceae	Baddeessaa	FG 0056	T
163	*Tagetes minuta* L.	Asteraceae		FG 0012	H
164	*Tagetes patula* L.	Asteraceae		FG 0163	H
165	*Teclea nobilis* Del.	Rutaceae	Hadheessa	FG 0023	T
166	*Thalictrum rhynchocarpum* Dill. & A.Rich.	Ranunculaceae	Mararree	FG 0055	H
167	*Tiliacora troupinii* Cufod.	Menispermaceae	Hidda Liqixii	FG 0174	Cl
168	*Tragia brevipes* Pax.	Euphorbiaceae		FG 0172	H
169	*Trifolium semipilosum* Fresen.	Fabaceae	Siddisa	FG 0196	H
170	*Triumfetta rhomboidea* Jacq.	Tliaceae	Hincinnii lagaa	FG 0191	SH
171	*Urera hypselodendron* (A.Rich.) Wedd.	Urticaceae	Laanqisaa	FG 0044	Cl
172	*Urtica simensis* Steudel	Urticaceae	Gurgubbee	FG 0031	H
173	*Vepris dainellii* (Pic-Serm.) Kokwaro	Rutaceae	Hadheessa	FG 0025	T
174	*Vernonia amygdalina* Del.	Asteraceae	Eebicha	FG 0059	T

Item No.	Scientific Name	Family	Vernacular Name (Afaan Oromoo)	Coll. No.	Habit
175	*Vernonia auriculifera* Hiern	Asteraceae	Reejjii	FG 0007	SH
176	*Vernonia leopoldi* (Sch.Bip.ex Walp)Vatke	Asteraceae	Sooyyoma	FG 0205	SH
177	*Veronica abyssinica* Fresen	Scrophulariaceae		FG 0206	H
178	*Vigna parkeri* Bak. ssp. *maranguensis* (Taub.) Verdc.	Fabaceae		FG 0075	H
179	*Vigna vexillata* (L.) Benth.	Fabaceae	Raamacaa	FG 0035	H
180	*Zehneria scabra* (Linn.f.) Sond.	Cucrbitaceae		FG 0130	Cl

Appendix 3: Selected tree species with their seedling, sapling and mature tree density/ha

Species	**Seedling**	**Sapling**	**Mature Tree/Shrub**
Albizia gummifera	107	32	18
Albizia schimperiana	87	56	20
Allophylus abyssinicus	157	103	55.6
Apodytes dimidiata	25	15	37.3
Bersama abyssinica	12	3	50.5
Celtis africana	15	6	16.5
Cassiporia malosana	38	21	7.07
Chionanthus mildbraedii	58	23	12.26
Canthium oligocarpum	56	13	12.26
Calpurnia aurea	24	0	11.8
Clausena anisata	36	12	41.04
Croton macrostachyus	51	43	64.62
Dombeya torrida	35	14	18
Ekebergia capensis	0	0	5.19
Erytrococca trichogyne	37	12	52.36
Euphorbia ampliphylla	3	0	15.56
Flacourtia indica	0	0	5.66
Ficus sur	14	5	43.4
Hagenia abyssinca	0	0	1.5
Macaranga capensis	0	0	9
Maytenus undata	25	5	26.9
Maesa lanceolata	43	20	31.13
Millettia ferruginea	13	0	6.6
Olea capensis ssp. *macrocarpa*	34	0	6.6
Olea welwitschii	19	0	18.8
Psycotria orophila	55	45	20
Pittosporum viridiflorum	78	36	25
Pouteria adolfi-friederici	125	56	65.1
Prunus africana	69	54	27.8
Ritchiea albersii	0	0	2.0
Rytigynia neglecta	98	74	88.7
Schefflera abyssinica	0	0	2.0
Syzygium guineense ssp. afromontanum	67	40	74.05
Teclea nobilis	140	58	22.6
Vernonia amygdalina	0	0	12.7
Vepris dainellii	367	151	26
Total/ha	**1888**	**897**	**952.83**

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

	Community				
Name of Species	**1**	**2**	**3**	**4**	P*
Acanthus eminens	7	20	**48**	15	0.0002
Justicia schimperiana	10	10	**54**	8	0.0002
Solanecio gigas	4	**68**	3	2	0.0002
Ficus sur	2	**56**	1	2	0.0004
Achyrospermum schimperi	**41**	11	18	0	0.0022
Periploca linearifolia	4	1	0	**41**	0.0024
Dracaena afromontana	0	1	2	**37**	0.0034
Cyperus distans	0	0	0	**32**	0.0048
Croton macrostachyus	**40**	10	24	7	0.0050
Landolphia buchananii	1	0	**32**	3	0.0064
Rytigynia neglecta	**40**	20	9	4	0.0066
Erythrococca trichogyne	25	4	**38**	2	0.0106
Pouteria adolfi-friederici	0	**41**	9	6	0.0128
Vernonia amygdalina	**30**	3	0	2	0.0176
Hibiscus macranthus	0	0	0	**27**	0.0178
Euphorbia ampliphylla	0	0	1	**25**	0.0252
Hippocratea goetzei	**25**	0	0	0	0.0256
Dracaena steudneri	1	**28**	3	3	0.0262
Solenostemon autranii	0	0	0	**20**	0.0408
Apodites dimidiata	11	5	9	33	0.0548
Abutilon longicuspe	1	5	2	27	0.0602
Rubus apetalus	19	0	0	0	0.0614
Clausena anisata	29	4	17	1	0.0616
Impatiens hochstetteri	19	0	0	2	0.0682
Pteris catoptera	0	15	0	0	0.0828

Name of Species	Community				P*
	1	2	3	4	
Pittosporum viridiflorum	3	2	25	11	0.0892
Hypoestes forskaolii	30	9	28	6	0.1102
Syzygium guineense ssp. *afromontanum*	6	15	31	32	0.1206
Ocimum lamifolium	0	2	15	0	0.1220
Dombeya torrida	12	5	0	24	0.1234
Dregea schimperi	0	0	11	0	0.1716
Momordica foetida	0	11	0	2	0.1870
Bidens ghedoensis	0	11	0	2	0.1906
Prunus africana	6	8	1	22	0.2020
Cyathula uncinulata	3	16	11	0	0.2320
Drymaria cordata	13	0	0	0	0.2380
Hagenia abyssinica	13	0	0	0	0.2390
Embelia schimperi	2	0	13	3	0.2438
Cynoglossum amplifolium	13	0	0	0	0.2448
Cyphostemma adenocaule	15	2	20	5	0.2462
Eriosema scioanum	13	0	0	0	0.2464
Kalanchoe densiflora	13	0	0	0	0.2529
Ritchiea albersii	13	2	0	0	0.2733
Vernonia auriculifera	24	14	29	9	0.2797
Achyranthes aspera	2	19	6	7	0.2807
Canthium oligocarpum	18	0	1	7	0.2855
Clematis simensis	9	5	19	3	0.2889
Zehneria scabra	0	2	0	10	0.2895
Hippocratea africana	1	0	10	0	0.2961
Maytenus undata	6	1	1	19	0.3133
Justicia diclipteroides ssp. *aethiopica*	2	0	7	0	0.3447
Millettia ferruginia ssp. *ferruginia*	9	0	0	2	0.3531

Name of Species	Community				P*
	1	2	3	4	
Olea capensis ssp.macrocarpa	0	12	8	1	0.3835
Desmodium repandum	0	8	0	0	0.4141
Sphaeranthus suaveolens	0	8	0	0	0.4155
Psychotria orophila	0	8	0	0	0.4159
Acalypha psilostachya	0	8	0	0	0.4159
Isodon schimperi	0	8	0	0	0.4199
Cassipourea malosana	15	7	1	3	0.4403
Thalictrum rhynchocarpum	8	0	0	2	0.4461
Calpurnia aurea	9	6	13	0	0.4503
Setaria megaphylla	0	3	0	8	0.4617
Acalypha marssima	8	0	0	2	0.4649
Solanum anguivi	12	14	5	0	0.4755
Abutilon martinium	1	6	0	0	0.4809
Maytenus gracilipes	1	0	9	1	0.4865
Albizia schimperiana	1	17	5	7	0.5007
Ekebergia capensis	2	4	2	11	0.5117
Bersama abyssinica	24	19	23	3	0.5193
Maesa lanceolata	21	13	4	9	0.5373
Crotalaria mildbraedii	1	0	7	2	0.5379
Hibiscus calyphyllus	12	9	5	0	0.5437
Schefflera abyssinica	6	0	0	7	0.5633
Asparagus africanus	8	0	7	12	0.5639
Rubus steudneri	6	12	0	14	0.5765
Pteridium aquilinum	4	8	5	14	0.6111
Allophylus abyssinicus	18	16	11	24	0.6289
Phytolacca dodecandra	7	0	5	0	0.6413
Albizia gummifera	5	12	6	1	0.6461

Name of Species	Community				P*
	1	2	3	4	
Echinops longisetus	3	4	0	0	0.6815
Macaranga capensis	0	4	9	8	0.6837
Triumfetta rhomboidea	0	0	0	7	0.6857
Sparmannia ricinocarpa	0	0	0	7	0.6901
Isoglossa somalensis	0	0	0	7	0.6965
Clerodendrum myricoides	0	0	0	7	0.6969
Acalypha ornata	0	0	0	7	0.7021
Panicum hochestetteri	0	0	0	7	0.7047
Mimulopsis solmsii	6	4	0	0	0.7101
Jasminum abyssinicum	6	1	3	1	0.7487
Rhus glutinosa	2	0	0	5	0.7622
Chionanthus mildbraedii	3	4	9	5	0.7626
Premna schimperi	2	0	0	5	0.7678
Urtica simensis	2	0	0	4	0.7698
Urera hypselodendron	18	16	23	17	0.7876
Flacourtia indica	2	6	8	0	0.7976
Brucea antidysenterica	11	12	11	1	0.8012
Olea welwitschii	0	4	0	3	0.8390
Teclea nobilis	11	10	17	15	0.8568
Vepris dainellii	18	6	17	17	0.8608
Vigna vexillata	5	2	0	0	0.8920
Satureja paradoxa	7	4	2	2	0.9154
Abutilon figarianum	6	0	0	0	1.0000
Celtis africana	1	2	4	1	1.0000
Combretum paniculatum	6	0	0	0	1.0000
Crassocephalum rubens	6	0	0	0	1.0000
Digitaria velutina	6	0	0	0	1.0000

Name of Species	Community				P*
	1	**2**	**3**	**4**	
Girardinia diversifolia	4	3	0	0	1.0000
Grewia ferruginea	6	0	0	0	1.0000
Leucas martinicensis	6	0	0	0	1.0000
Maytenus addat	1	2	4	1	1.0000
Pycnostachys meyeri	3	0	2	2	1.0000
Tagetes minuta	6	0	0	0	1.0000
Tragia brevipes	3	2	3	3	1.0000
Ceropegia sobolifera	6	0	0	0	1.0000

Declaration

I, the undersigned, declare that this thesis is my original work, it has not been presented in other Universities, colleges or institutions, seeking for similar degree or other purposes. All sources of the materials used in the thesis have been only duly acknowledged.

Name Signature

The work has been done under our supervision.

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