Ecological Study of the Vegetation in Choke-Koso Ber Mountain Range, Northwest Ethiopia

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Presented in Fulfillment of the Requirements for the Degree of Doctor of Philosophy (Plant Biology and Biodiversity Management)

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By

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A Thesis Presented to the Graduate Programmes of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy (Biology: Botanical Sciences)

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Abstract

Ecological Study of the vegetation in Choke-Koso Ber Mountain range was conducted in Gojjam, Amhara zone, Northwest Ethiopia, to identify and describe floristic composition, diversity, community types, community-environment relation, population structure and regeneration status. A total of 212 sample plots, each with a size of 20 m x 20 m, were systematically laid at 25 m altitudinal intervals along transect lines. In each plot, geographical coordination, altitude, aspect, slope and identity of woody species were recorded; percentage aerial cover of the species was estimated. Height and circumference at breast height (CBH) were measured for each woody species with height ≥ 2.5 m and CBH ≥ 7.85 cm. In five small sub-plots, herb species were recorded, percentage aerial cover of the species was estimated, seedling and sapling of woody species were counted and composite of soil samples were collected. Soil texture was determined using the Boycouos hydrometric method and USDA Soil Textural Triangle. Soil pH was measured using pH meter, while electrical conductivity and total dissolved salts of the soil samples were measured using Conductivity/TDS/Salinity/ Resistivity Meter. Diversity and multivariate analyses were conducted using appropriate packages in R program (Version 3.1.2).

243 plant species, belonging to 177 genera and 71 families, were recorded. Of these, 17 species (7%) were trees, 3 species (1.23%) shrub/tree, 37 species (15.23%) shrubs, 171 species (70.37%) herbs, 12 species (4.94%) climbers and 3 species (1.23%) mosses. Out of the total identified species, flowering plants were represented by 228 species (93.83%), non-flowering by 15 species (6.17%), dicots by 176 species (77.20%) and

monocots by 52 species (22.80%). Asteraceae, Poaceae, Fabaceae and Lamiaceae were the dominant families. Of the total species, 33 species (13.58%) were endemic plants to Ethiopia. Agglomerative Hierarchical Cluster analysis resulted in three plant community types of Afroalpine vegetation and five plant community types of Dry Evergreen Afromontane vegetation. Analysis of Shannon and Weaver diversity index showed that species richness, diversity and evenness varied among the plant communities. Diversity and richness tended to decrease with increasing altitude, while species turnover tended to increase with increasing altitude. In general, community types with largest number of sample plots, diversified environment, highest altitudinal range and moderate disturbance were found to have the highest species diversity, richness and evenness.

Soil textural classes of the study area were sandy loam, loamy sand, sandy clay loam, clay loam and loam. The vegetation and the environmental data were subjected to direct gradient analysis. The output of CCA revealed that the most influential environmental variables that had effect on the distribution of species and segregation of some plant community types in both Afroalpine and Dry Evergreen Afromontane vegetation were Sand (%), Disturbances, Aspect and Slope.

ANOVA and Turkey's pair-wise comparison showed significant different ($P \leq 0.05$) between the community types with respect to mean of Altitude, Silt (%), Clay (%) and Disturbance in both Afroalpine and Dry Evergreen Afromontane vegetation. In addition, there was significant difference between the community types of Dry Evergreen Afromontane vegetation with regard to mean of Sand (%), pH, EC and Total dissolved

Salt (TDS). Pearson's correlation test for environmental variables of Afroalpine showed significant positive correlation ($P \leq 0.05$) occurred between Sand (%) and pH, Silt (%) and Disturbance, and EC and TDS. On the contrary, significant negative correlation occurred between Altitude and Slope, Sand (%) and Slope, Sand (%) and Silt (%), Sand (%) and Clay (%), Silt (%) and Clay (%), and TDS and Disturbance. Similarly, the correlation test for environmental variables of Dry Evergreen Afromontane vegetation showed significant positive correlation between Altitude and Aspect, Slope and pH, Sand (%) and EC, Sand (%) and TDS, and EC and TDS. In contrast, significant negative correlation occurred between Altitude and Disturbance, Sand (%) and silt (%), Sand (%) and Clay (%), Silt (%) and EC, Silt (%) and TDS, Clay (%) and EC, and Clay (%) and TDS.

Structure analysis was carried out for the Dry Evergreen Afromontane forest. In general, woody species had high density in the lower DBH and height classes, and the density gradually decreased with increasing DBH and height classes. The dominance of small-sized woody individuals in the lower DBH and height classes indicated the characteristic of a good regeneration status. Four patterns of population structure were identified: Inverted J-shaped, Gaussian-curve, J-shaped and U-shaped. The total basal area of woody species was 28.65 m^2/ha. The six most important woody species were *Maytenus arbutifolia*, *Maesa lanceolata*, *Acacia abyssinica*, *Schefflera abyssinica*, *Prunus africana* and *Pittosporum virdiflorum.* These woody species represented 71.96% of the total Important Vale Index. The remaining 28.04% was contributed by eighteen woody species.

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OF ACRONYMS

AAU	Addis Ababa University
CBH	Circumference at Breast Height
CBD	Conservation on Biological Diversity
EARO	Ethiopia Agricultural and Research Organization
EC	Electric conductivity
EEA	European Environment Agency
ETH	National Herbarium of Ethiopia
FAO	Food and Agriculture Organization of the United Nations
FEE	Flora of Ethiopia and Eritrea
GPS	Global Positioning System
IBC	Institute of Biodiversity Conservation
ITCZ	Inter Tropical Convergence Zone
IVI	Important Value Index
IUFRO	International Union of Forestry Research Organization
MoA	Ministry of Agriculture
MoNRDEP	Ministry of Natural Resource Development and Environmental Protection
NAPA	National Adaptation Program of Action
NMA	National Meteorological Agency
NMSA	National Meteorological Services Agency
ORDA	Organization for Rehabilitation and Development in Amhara
SNNP	South Nations, Nationalities and People
TDS	Total Dissolved Salts
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United State Department of Agriculture
WCMC	World Conservation Monitoring Centre

CHAPTER ONE

1. Introduction

The Ethiopian Highlands are the largest mountain complex comprising over 50% of the African land area covered by Afromontane vegetation (White, 1983; Yalden, 1983; Tamrat Bekele, 1993; App *et al*., 2008; Hurni*, et al.,* 2010). The higher mountain massifs and volcanic cones that often higher than 4000 m are scattered over the highlands (Friis *et al.* 2011). These Highlands are home to more than 90% of Ethiopia's population (over 80 million people, estimated in 2010) and 60% of the livestock (Hurni, *et al*., 2010). They also estimated that about 90% of the area was suited for agriculture.

About 20 thousand hectares of forest are harvested annually in the Amhara Region of Ethiopia for fire-wood, logging and construction purposes, consequential about 1.9 to 3.5 billion tones of fertile topsoil are washed away annually into rivers and lakes due to deforestation alone (BoA, 1997).

The Choke-Koso Ber Mountains rang extends from East to West Gojjam, Amhara Region, Northwest of Ethiopia. The study area on the Choke Mountains was situated in Afroalpine region between 3430-4080 m a.s.l, whereas the other study areas on Kurub, Chung, Kasakan, Guble and Darken Mountains were situated in Afromontane region between 2480-2735 m a.s.l. Thus, based on the criteria of Zerihun Woldu (1999) and Friis *et al.* (2011), the vegetation of study areas was categorized under Afroalpine and Dry Evergreen Afromontane Vegetation (section 1.9.2).

The Choke Mountains (known to be water tower of the Blue Nile basin) cover area about 17,443 km^2 and source of more than 23 major rivers and 273 small streams flowing to Blue Nile as major tributaries(ORDA, 2011). Encroachment, expansion of farmland (now up to 3800 m elevation), overgrazing, clearing and selective cutting, firewood collecting, land degradation and erosion are the major threats to the natural vegetation and the ecosystem of Choke Mountains. Aramde Fetene *et al*. (2014) reported that the cropland had increased by 206% between 1986 and 2011, whereas ericaceous forest, grasslands and shrub lands have decreased by 79, 40 and 17%, respectively in Afroalpine region of the mountain range in the same period. For instance, in the year 2011, about 132,069 families engaged in traditional farming on Choke Mountains and around 4,500 youths were landless (ORDA, 2011). In addition, Within 20 years (1986 - 2005), 607 km^2 wetlands and 22.4 km^2 water body has been lost from Choke Mountains (Ermias Teferi *et al*., 2010). Similarly, the size of natural forest of Kurub-Darken Mountain range is gradually shrinking. Collecting fire-woods, introducing livestock in to the forest and selective cutting for the need of constructing materials (house, fence, and house hold materials) are some of the anthropogenic factors which may have lead to the decimation of the vegetation cover. Medium-textured soils (loamy soil) tend to be most erodible because they have high amount of silt and fines sands O'Geen (2006). For that reason, loamy soil was the dominant texture in the study area, which needs attention because of its high erodible property.

Species diversity and endemism is generally higher in mountain areas than in lowlands as a result of topographical isolation of populations, diverse habitat associated with sharp altitudinal gradients in temperature and precipitation and speciation processes over geological time scales (Regato and Salman, 2008; Schmitt, 2009). Consequently, out of 244 plant species recorded in the Choke-Koso Ber Mountains rang, 33 species were endemic to Ethiopia. On the other hand, Aramde Fetene *et al*. (2014) recorded only 31plant species from the Afroalpine vegetation of Choke Mountain range, but in this study, 142 species were recorded from the same Afroalpine vegetation. In addition, the study showed that 49 extra plant species were unregistered in the Gojjam (GJ) Floristic Region of Flora books yet.

Though general and specific studies have been conducted in Ethiopia, detailed ecological investigations of the natural vegetation was lacking in Choke-Koso Ber mountain range. Even though mountainous ecosystems are center of high biodiversity and endemism (Regato and Salman, 2008), they are exceptionally fragile and vulnerable (Körner and Ohsawa, 2005). Because of the sloping terrain and the relatively thin soils, the recovery of mountain ecosystems from disturbances is typically slow or may not occur (Körner and Ohsawa, 2005). Therefore, a detailed study on the vegetation ecology of the Choke-Koso Ber mountain range can be the basis for defining, designing and implementing conservation strategies to secure sustainable ecosystem services. Since the Renaissance hydropower dam of Ethiopia is being constructing below the basin of this study area, there is a risk of accelerated siltation in the dam due to the high erosion rate in the catchment unless urgent actions to abate the loss of vegetation cover is put in place.

1.1. Research questions

- What are the plant composition and community types in the natural vegetation of the Ckoke-Koso Ber Mountain Range?
- What are some physical and biotic environmental factors related to the distribution of plant species and community types in the mountain range?
- How is the conservation status of some of the plant species in the mountain range?
- What would be the contribution of the rehabilitation of the mountain range to downstream areas?

1.2. Research objective

The general objective of this research is to study vegetation ecology of Coke-Koso Ber mountain range with the following specific objectives**:**

1. to determine and describe the floristic composition, plant community types and diversity
2. to investigate and explain the relationship between plant community types and environmental variables
3. to determine population structure and asses the regeneration of trees and some shrubs

CHAPTER TWO

2. Literature review

2.1. Physical geography of Ethiopia

Ethiopia has extremely varied topographic features (FAO, 1984; Magin, 2001) dominated by rugged mountains that are divided by river valleys and deep gorges, flat-topped plateau, undulating hills and lowland plains (Beals, 1968; Friis, 1992; Tamrta Bekele, 1993). The Great African Rift Valley runs diagonally across the country from northeast to southwest dividing the highland massif into western and southeastern highlands. These highlands of Ethiopia have a general elevation ranging from altitude of approximately 1500 to 3000m, but most areas are below 2500 m altitude (Friis *et al.* 2011). According to Zerihun Woldu (1999) the extensive highland plateau, with an altitude of over 2,500 m a.s.l., covers 40 percent of the country. The higher mountain massifs and volcanic cones that often higher than 4000 m are scattered over the highlands (Friis *et al.* 2011). The Ethiopian Highlands are home to more than 90% of human population of Ethiopia (over 80 million people, estimated in 2010) and 60% of the livestock, and 90% of the area suited for agriculture (Hurni, *et al.*, 2010).

About 50 percent of African mountains (approximately 371,400 km^2 of land above 2,000 m) are found in Ethiopia (Yalden, 1983; Alemayehu Mengistu, 2003). Semien Mountains (such as Ras Dejen and Bwahit), Amb-Alge, Abune Yoseph, Guna, Amba Farit, Abuye Meda, Choke and Gurage Mountains are found in Western Highlands of Ethiopia, whereas Arsi Mountains (such as Chilalo, Badda and Kaka), Bale mountains (such as Batu and Tulu Dimtu) are located in Eastern highland of Ethiopia (Friis *et al.*2011).

Table 1. Some of the highest elevated mountains in Ethiopian highlands where Afroalpine are located

(Source: Friis *et al*., 2011; Uhlig and Uhlig, 1991)

Name of the Mountain peak	**Elevation (m a.s.l)**	**Location**
Ras Dejen	4563	North Gondar, Amhara Region
Abba Yared	4460	North Gondar, Amhara Region
Silki	4420	North Gondar, Amhara Region
Tulu Dimtu	4377	Bale, Oromya Region
Batu	4307	Bale, Oromya Region
Abyue Meda	4305	North Shewa, Amhara Region
Abune Yoseph	4280	North Wollo, Amhara Region
Guna	4231	South Gondar, Amhara Region
Kaka	4190	Arsi, Oromya Region
Guge Highlands	4176	Gamogofa, SNNP
Chilalo	4139	Arsi, Oromya Region
Choke	4070	East Gojjam, Amhara Region
Amba Farit	3975	Norh Wollo, Amhara Region
Gurage	3721	Gurage zone, SNNP
Amba Alge	3939	South Tigray, Tigray region
Gara Muleta	3405	West Harar, Oromya Region

The Choke – Kosso Ber Mountains, on most occasions situated above 2100 m a.s.l, are located in Abay (Blue Nile) basin of the western highlands of Ethiopian (Gani *et al*., 2007; Neupane, 2011; Belay Simane, 2013).

2.2. Major Mountain Belts

The three belts along mountain regions where precipitation regimes allow vegetation growth are the *Montane belt,* the *Alpine belt* and the *Nival belt* and the range of altitude occupied by each belt is varying according to latitude (Körner and Ohsawa, 2005). Similarly, Hedberg (1969) recognized three belts on high mountains of East Africa: They are a *Montane forest belt*, *a (subalpine) ericaceous belt*, and *an Afroalpine belt*; however the term '*Nival belt*' is not mentioned.

The *Montane belt* extends from the lower mountain limit to the upper thermal limit of forest (irrespective of whether forest is present or not) and this limit has a mean growing season temperature closer to at temperate latitudes (Körner and Ohsawa, 2005). On the high mountains of East Africa, the belt is limited between 1500 and 3200 m altitudes (Hedberg, 1951, 1964 and 1957; Tewolde Berhan Gebre Egziabher, 1988).

The *Alpine* (*Afro-alpine*) *belt* is a treeless region between the natural climatic forest limit and the snow line. Land cover is dominated by grassland or low stature shrubs (Körner and Ohsawa, 2005). According to Hedberg (1951 and 1957) and Tewolde Berhan Gebre Egziabher (1988), the areas, which on the average higher than 3200 meters above sea level, are generally referred to as the Afroalpine and Sub-Afroalpine. The Sub-Afroalpine areas range between 3200- 3500 m. These areas include chains of mountains, mountain slopes and tops of highest mountains in Ethiopia. According to Friis *et al*. (2011), the upper and lower limit of Ericaceous belt (Sub-Afroalpine) is quite difficult to define, but arbitrarily, this vegetation type occurs between 3000 and 3200 m. Ethiopia has the largest extent of Afroalpine habitats in Africa (Yalden, 1983), These high mountains are mainly distributed in western and eastern highlands of the country.

The *Nival belt* is defined as the elevation where snow is commonly present all year round (though not necessarily with full cover).

2.3. Services and fragilities of mountain ecosystem

Mountains are unique features of the Earth system in terms of their climates and ecosystems (Beniston, 2000) as a result species diversity is generally higher in mountain areas than in lowlands due to diverse habitat associated with sharp altitudinal gradients in temperature, precipitation (Regato and Salman, 2008). Mountains support about one quarter of terrestrial biodiversity, with nearly half of the world's biodiversity hot spots concentrated in mountains (Körner and Ohsawa, 2005; Theurillat and Guisan, 2001). For instance, globally, there are some 10, 000 species of flowering plants in the alpine belt alone, representing about 4% of all known species and covering about 3% of the vegetated land area (Körner, 1995). In addition, mountains ecosystems are often center of endemic species, because many species remain isolated at high elevations compared to lowland vegetation communities that can occupy climatic niches (Beniston, 2006). For that reason, 32% of all protected areas are located in mountainous regions, providing habitats for rare, relict, and endangered plants and animals (UNEP-WCMC, 2002).

Over 40% of the global population lives in the watersheds of rivers originating from different mountain ranges (Beniston, 2000). They maintain ecological processes and provide goods and services. Water (for drinking, irrigation and hydropower), fuelwood, game and medicinal plants are some of the resources. Mountains are also important as centres of crop diversity and a source of "wild foods". Modulating climate, carbon sequestration, recycling of water as well as air and nutrient are main regulating services in mountain ecosystem. Recreation/tourism, aesthetic values and spiritual heritage are examples of cultural services of mountains (Körner and Ohsawa, 2005; EEA, 2010).

Mountain ecosystems are exceptionally fragile and vulnerable. Mountains are subject to both natural and anthropogenic drivers of change. Volcanic and seismic events, flooding, global climate change, inappropriate agricultural practices and extraction of raw materials for industries are some of the factors that affect mountain ecosystems. Mountain biota are adapted to relatively narrow ranges of temperature (and hence altitude) and precipitation. Because of the sloping terrain and the relatively thin soils, the recovery of mountain ecosystems from disturbances is typically slow or may not occur (Körner and Ohsawa, 2005). Climate change affects the relative importance of the total moisture flux and how it is delivered temporally (Beniston *et al.*, 1996). Land use pressure puts mountain ecosystem integrity at risk in many parts of the world. Forest destruction, overgrazing, and inappropriate agriculture practices may lead to irreversible losses of soil and ecosystem function, with increased environmental risks in both mountains and adjacent lowland areas (Körner and Ohsawa, 2005).

2.4. Mountain Climate

Mountain ranges account for about 25 percent of the Earth's land surface, the meteorology of most mountain areas is little known in detail (Barry, 2008). Four principal factors influence mountain climates are altitude, continentality, latitude, and topography.

Altitude effects: total atmospheric pressure, temperature and air density decrease with increasing altitude whereas wind velocity, radiation under cloudless sky and precipitation increase with increasing altitude. The air pressure, such as partial pressures of oxygen and carbon dioxide, decreases by about 10% for every kilometer of elevation (Körner and Ohsawa , 2005; Körner, 2007: Barry 2008). This reduction in pressure and partial pressure has a significant impact on respiration in animals and on gas exchange in plants. On average, temperature declines by 5.5 ^{0}C per kilometer of elevation (but differs diurnally, seasonally, latitudinally, and from region to region). The altitudinal temperature gradient in mountains is about 600–1,000 times higher than the corresponding latitudinal gradient (Körner and Ohsawa, 2005).

A reduction in ambient air temperature reduces the saturation vapor pressure (the capacity of the air to hold moisture), which also sets lower boundaries for vapor pressure deficit, thus reducing evaporative forcing at high elevation when the temperature of the evaporating surface is close to (or cooler than) air temperature (Körner, 2007). Clear sky solar radiation increases with altitude, and higher maximum radiation and a greater short wave radiation (UV) are typical for higher elevations. However, clouds and fog may reverse altitudinal trends in solar radiation (Yoshino, 1975; Barry, 1992; Körner, 2003).

Within mountain regions, species richness decreases with increasing altitude, largely in proportion to the available land area (Körner, 2000), but species endemism, in particular, often increases with altitude, partly due to the topographical isolation of populations and speciation processes over geological time scales (Regato and Salman, 2008; Schmitt, 2009). Discernible vegetation belts on mountains may commonly span an elevation range of 1,000 meters. Over such a range, the temperature change is about 5–6 ^{0}C, enough to cause a full bioclimatic vegetation belt to be replaced by another (alpine by montane forest, for example) (Körner and Ohsawa, 2005). Cloud cover is more frequent and thicker, in general, over mountains than over the surrounding lowlands. The ability of mountains to generate clouds at any given time depends on: the atmospheric conditions – moisture content and stability and the moisture lifting caused by mountains. There are three main processes that cause air to be lifted: direct forced ascent, aerodynamic effects (when airflow is deflected around an obstacle) and thermal forcing over mountain slopes (Banta, 1990 cited in Barry, 2008).

Continentality effects: Continentality refers to the proximity of a particular region to an ocean. Increased annual/diurnal temperature range, modified cloud and precipitation regimes are effects of continentality. Generally, the more water dominated an area is, the more moderate its climate. Significance of mountains in accentuating continentality depends primarily upon latitude and their distance from the ocean and prevailing winds direction. Extensive mountain massifs and high plateaus set up their own large-scale and local-scale circulations. Such large-scale effects on diurnal and seasonal circulations (‘‘plateau monsoons’’). High mountains also protrude into the middle troposphere where the atmospheric circulation may differ considerably from that at sea level. For these reasons, mountain ranges located in a semi-arid macroclimatic zone, for example, may have distinctly different climatic characteristics and vegetation assemblages from the adjacent lowlands (Barry, 2008).

Latitudinal effects: Latitude determines length of day and angle of incoming sunlight and, thus, solar radiation and temperature broadly decrease with increasing latitude, as a result, the belt of alpine vegetation and permanent snow and ice are represented on much lower mountains in high latitudes than in the tropics. Latitudinal differences in mountain climates are also affected by characteristics of the global atmospheric circulation, consequently, tropical mountains are within the easterly trade wind regime (Barry, 2008).

Topographic effects: According to Barry (2008), the dimension, shape, slope and aspect of a mountain affect the regime of its climate. The dimensional characteristics of the barrier including height, length, width, and the spacing between successive ridges modify air motion. The orientation of mountain ranges also modifies the regimes of temperature, evaporation, convection, and thermally induced wind circulations, as a result of the reduction of solar radiation receipts on equatorward- (poleward-) facing slopes. Slope angle and aspect (or orientations) have fundamental effects on radiation income and temperature conditions. In the high mountains, especially above the tree line, plant and animal life is strongly controlled by the climate at and near the ground surface – the microclimate. Additionally, the spatial pattern of microclimate forms a mosaic due to the effects of topography, which cause distinctive topoclimates.

2.5. Geology

Mohr (1971), Kazmin, (1972), Mengesha Tefera *et al*. (1996), Gani *et al*. (2008) and Friis *et al*. (2011) have given a clear account of the Geology of Ethiopia (I - III, section 2.6.1 below).

2. 5. 1. Bedrock

The geology of Ethiopia broadly is composed of Precambrian basement, Paleozoic-Mesozoic sediments and Cenozoic volcanic rocks.

I. *The Precambrian rock* is a basement rock which consists of a wide variety of metamorphic, igneous and intrusive rocks. Metamorphosed sandstone, schists, amphibole, chlorite, quartzite and quartizo-feldspathic rocks, as well as occasional intrusion of granites are main specific components of the rocks. This oldest rock upon which younger rocks formation overlie has fundamentally important tectonic position it occupies. It covers approximately 23% land mass of Ethiopia and exposed in areas where the younger cover rocks have been eroded away, such as in many deep river valleys. They are mainly exposed in Northwestern (Gojam and Wellega), northern (Gondar and Tigray), eastern (Harar), and southern (Sidama, Bale and Illuababora) part of the country. Marbles, granitoids, soapstone and most of the presently known metallic deposits of Ethiopia are some of the components of the exposed Precambrian rocks.

II. *The Paleozoic-Mesozoic sedimentary rocks* are composed of mainly sandstones and limestones overlie the Precambrian basement rock and cover about 25% of the country's landmass. These thick successions of rocks are exposed mainly in eastern, central and southern Ethiopia. A thick succession of Palaeo-Mesozoic sediments is represented by three distinct sedimentary basins; namely: the Abay (Blue Nile) Basin, Ogaden Basin, and the Mekele Basin. Based on field and remote sensing studies along the Gorge of the Nile, Gani *et al*. (2008) outlined the stratigraphic and structural evolution of the Blue Nile Basin. According to them, the Blue Nile Basin is composed of approximately 1400m thick Mesozoic sedimentary section underlain by Neoproterozoic basement rocks and overlain by Early–Late Oligocene and Quaternary volcanic rocks.

III. *The Cenozoic volcanic rocks* cover about 44% of the country's landmass and form the spectacular Ethiopian highlands and the Main Ethiopian Rift. These rocks are found in deep gorges in the Northwestern High lands, in the highly eroded lands of northern Ethiopia and southeastern slopes of the SE Highlands. During the Tertiary period of Cenozoic Era, the outpouring of vast quantities of basaltic lava over the large part of the country was accompanied by; and alternated with; the eruption of large amounts of ash and coarser fragmental material, forming the a series of layers is called Trap Series (44%) which now cover the Mesozoic rocks. Rhyolites, trachytes, tuffs, ignimbrites and basalts are some of the components.

A dramatic uplift of the highlands marked the beginning of the Tertiary periods. This was accomplished by massive outpour of lava from numerous volcanoes. The northwestern Ethiopian Plateau was uplifted due to the combined effects of the rising Afar mantle plume and flank uplift of the Main Ethiopian Rift and the Afar Depression. Plume-related uplift caused deep-seated faults within the Ethiopian lithosphere, leading to the collapse that formed the Afar Depression ca. 24 Ma. This event was followed by shield-volcano–building episodes, which gave rise to the development of Choke and Guguftu volcanoes in the northwestern Ethiopian Plateau in Mio-Pliocene of Cenozoic Era (Alebachew

Alebachew Beyene and Abdelsalam, 2005). The majority of highlands consist of volcano rocks including rhyolites, trachytes, tuffs, ignimbrites, agglomerates, and basalts. These rocks, the major part of which is basaltic, have considerable thickness, reaching a maximum of 3000 to 3500 m.

According to Mohr (1971), the highlands of Ethiopia were formed between 40 and 25 million years from the present by lava outpouring of the trappian series in the Miocene and Oligocene. Most Ethiopian highlands are formed of basalt; through Precambrian rocks date from the Eocene and have been intermittently increased by subsequent eruptions which have continued into the Quaternary (White, 1983). Thus, the mountains are volcanic in origin dominantly overlie Precambrian basaltic and trachytic bedrocks (Tewolde Berhan Gebre Egziabher, 1988).

2.5.2. Soil

The Afromontane 'archipelago' is very diverse in lithology and physiology, which have been little studied from botanical point of view (White, 1983).The soils developed over volcano rocks are principally Nitosols and in some areas Lithosols (Magin, 2001) but according to Last (2009) and http://www.fao,org/ cited in Friis *et al*. (2011), Vertisols account for 24% of all the cultivated areas in the highlands of Ethiopia. In addition, red or brown Ferralsols derived from volcanic parent materials found in highlands where the rainfall is relatively high. As it is seen on soil map of world (http://www.fao,org/) the soil type in the Awi zone, where part of this study is conducted, is composed of Fluvisol.

According to the map of soil type of Ethiopia, ILRI (International Livestock Research Institute) cited in Friis *et al*. (2011), the dominant soil types of the Choke Mountains are Chromic Luvisols, Humic Nitosols and Eutric Vertisols.

Most mountains of Alpine belt attract much rain but moisture in the soil could be limiting as water stays in form of heavy frost or ice and snow for prolonged time, and thus the amount of soil water available is the most important factor influencing the distribution of plant (Ensermu Kelbessa *et al*., 1992). The extent of humus accumulation is also largely depends on the degree of moisture available, and temperature conditions. Within the alpine belt, therefore, the extent of humus accumulation appears to decrease with increasing altitude (Menassie Gashaw and Masresha Fetene, 1996).

2.6. Climate of Ethiopia

2.6.1. Climate classification

Based on altitude and temperature, five broad climatic zones are traditionally recognized in Ethiopia, namely: 'Wurch', 'Dega', 'Woina-Dega', 'Kolla' and 'Bereha' (Daniel Gemechu, 1977) (Table 2). According to this classification, the Choke–Koso Ber Mountain range falls in ‘Wurch’, ‘Dega’ and ‘Woina- Dega’ climatic zones.

The climate of Afroalpine (‘Wurch’) ecosystem is governed by two fundamental geographical circumstances: the vicinity to the equator, and the high altitude above sea level (Hedberg 1964). These circumstances make the climate of Afroalpine is extremely different from other ecosystems (White 1983), but there is resemblance of the Afroalpine climates of the different high East African Mountains with substantial differences.

Table 2. Traditional climatic zones with physical characteristics

(Source: MoA, 2000)

Climatic Zone	Description	Altitude (m)	Annual Rainfall (mm/year)	Average annual temperature (°C)
'Wurch'	Cold, highlands	> 3000	900-2200	< 11.5
'Dega'	Cool, highlands	2500-3000	1200-2200	11.5-16.0/17.5
'Woyna- Dega'	Temperate, highlands	1500-2500	800-1200	16.0/17.5-20.0
'Kolla'	Warm and arid, lowlands	500-1500	200-800	20.0-27.5
'Bereha'	Hot and hyper-arid	< 500	< 200	> 27.5

2.6.2. Rainfall

The climate pattern of Ethiopia is mainly determined by the inter-annual movement of the Intertropical Convergence Zone (ITCZ), following the position of the sun relative to the earth and associated atmospheric circulation modulated by the complex topography of the country (Liljequist, 1986; NMSA, 2001; Tamiru Alemayehu, 2006). ITCZ is an area of low pressure that forms where the Northeast Trade Winds meet the Southeast Trade Winds near the earth's equator. The position of ITCZ governs the direction of dry or moisture-bearing seasonal air streams and seasonal rainfall (Kebede, 1964; Daniel Gemechu, 1977; NMSA, 2001).

The oscillatory movement of ITCZ causes three seasons in most area of the country, namely, 'Kiremt' (long rain season) which extends from June-September, 'Bega' (dry season) which extends from October-January and ‘Belg’ (short rain season) which extends from (February-May) (NMA, 2007). According to Daniel Gemechu (1977), Liljequist (1986), NMSA, (1996), NMSA (2001), Camberlin and Philippon (2001) and Tamiru Alemayehu (2006), most parts of the country experiences one main rainy season (called ‘Kiremt’) and normally receive highest rainfall (50-80%).When the ITCZ is at its northern most of the equator, South-Westerly Trade Winds are set from South Atlantic Ocean. These moisture laden winds blow over the humid regions of the Gulf of Guinea, the Congo basin, Central Africa via to Ethiopia. The moisture-laden winds ascend over Ethiopian highlands, cool and finally cause summer rain over most parts of the country specially southwestern, central and north of the country. Though the summer (Kiremt) is the main rainy season which occurs from May to September, the highest rainfall occurs in the southwestern parts of highlands where the ascent of the winds are the steepest and the amount of rainfall gradually decreases as the winds move north and northeastwards. During this season (Kiremt), southerly winds are also set from Indian Ocean. These moisture laden winds blow to southeast of the country.

When the ITCZ moves to the south, the country will be under the influence of continental air currents from north and northeast. These cold and dry winds originate from North Africa (Sahara) and West Asia cause dominant dry season known as ‘Bega’. During this season, North-Easterly Trade Winds are also set from Arabic Peninsula. These winds are cold and carry little moisture from Red Sea which is soon spent over the area around the Red sea coastal plains, including the Afar region and only little rain falls on the highlands during these months (Liljequist 1986; Camberlin and Philippon, 2001). In the ‘Belg’ (February to May) the ITCZ lies in the southern part and a strong cyclonic cell (low pressure area) develops over Sudan. Winds from the Red Sea and the Indian Ocean (anticyclone) blow across central and southern Ethiopia and form the relatively smaller 'Belg' rains (Tamiru Alemayehu, 2006).

Based on the annual rainfall distribution patterns, three major rainfall regimes can be identified in Ethiopia (Tesfaye Haile and Yarotskaya, 1987; Tamiru Alemayehu, 2006).

1. The south-western and western areas of the country are characterized by mono-modal rainfall ('Kiremt'), but the length of the wet season decreasing northwards.
2. The central, eastern and northeastern areas of the country experience a nearly bi-modal rainfall distribution. These are the 'Belg' rains (February to May) and 'Kiremt' rains (June to September).
3. The southern and southeastern areas of the country are dominated by a distinctly bi-modal rainfall pattern. Rain falls during September to November and March to May with two distinct dry periods separating the two wet seasons.

The study areas (Choke–Koso Ber Mountain range) receive mono-modal rain during 'kiremt', typically from June to September. Mean annual rainfall gradually decreases towards the northeast and east. In central and north-central Ethiopia, the annual amount is moderate, about 1100 mm. In some places, it reaches over 2,000 mm as for example western Agewmidir, south eastern Metekel and north of Kola Dega Damot in Gojam. In general, Mean annual rainfall distribution over the country is characterized by large spatial variation which ranges from about 2000 mm over some pocket areas in the

Southwest to about less than 250 mm over the Afar lowlands in the Northeast and Ogaden in the Southeast (NMSA, 2001).

Regional variation in rainfall in Ethiopia is not only determined by the direction of moisture-bearing seasonal air currents, but also the elevation (Kebede Tato, 1964; Daniel Gemechu, 1977). According to FAO (1984), precipitation and temperature gradients are strongly dependent on altitude; while precipitation increases, temperature decreases with increasing altitude. Rainfall in Ethiopia is generally correlated with altitude. Middle and higher altitudes (above 1,500 m) receive substantially greater rainfalls than do the lowlands, except the lowlands in the west where rainfall is high.

2.6.3. Temperature

Temperature varies greatly with altitude though Ethiopia experiences mild temperatures for its tropical latitude because of topography. The temperature decreases towards the interior of the country where much of the area is mountainous. Mean annual temperature distribution over the country varies from about 10^0C over the highlands of northwest, central and southeast to about 35^0C over north-eastern lowlands. Lowest annual minimum temperatures occur over the highlands particularly between November and January. Temperatures lower than 5^0C occur during high rainfall months (July and August) over the plateau in Northwest, Central and Southeast due to high cloud cover (NMSA, 2001; NMA, 2007). The ‘Belg’ months (March, April and May) are the warmest months almost all over the country when the annual extreme maximum temperatures are observed in many places. The ‘Bega’ months (November, December and January) are the coldest months (Mengistu Tsidu and Eyale Bayable, 2011). On the other hand, Ethiopia has been acquiring a warming trend in the annual minimum temperature over the past 55 years. It has been increasing by about 0.37^0 C every ten years (NMA, 2007).

Afroalpine and Sub-Afroalpine environments are peculiar in that there is no seasonal variation in temperature, but rather pronounced diurnal variations with nightly frosts all the year round, and with intense sunshine in daytime i.e., pronounced diurnal variations with "summer every day and winter every night" with strong insolation and outward radiation, frequent frost heaving on bare soil all year round, though, the incidence of frost varies considerably from complete absence on some lower slopes to a nightly occurrence on the highest summits (Hedberg, 1964 and 1995). Estimates of the mean maximum temperature on the higher peaks are between 6 and 12°C while mean minimum temperature is between 3 and 10°C (Rundel, 1994). For example, in Simien Mountains National Park, the recorded temperatures range from a minimum of -2.5 to 18°C, while -15 to 26°C on the Sanetti Plateau of the Bale Mountains (Hedberg 1997).

2.7. Vegetation map of Ethiopia

Making of a complete and satisfactory vegetation map of Ethiopia has been rather difficult. Zerihun Wldu (1999) pointed out that the vegetation of Ethiopia is complex due to great variations in altitude implying equally great spatial differences in moisture regimes as well as temperatures within very short horizontal distances.

Many authors have made significant effort to delimit and describe the vegetation type of Ethiopia. Pichi-Sermollis (1957), White (1983), Sebsebe Demissew *et al*. (1996), Zerihun Woldu (1999), Friis and Sebsebe Demissew (2001), Sebsebe Demissew *et al*. (2004) and Friis *et al*. (2011) are few of them. Detailed information about attempted works on classifying the vegetation of Ethiopia is available in Zerihun Woldu (1999) and Friis *et al*. (2011).

2.7.1. Vegetation map of Ethiopia drawn by Pichi Sermolli (1957)

His vegetation map covers Eritrea, Ethiopia, Djibouti and Somalia. He used 24 mapping units, out of which 22 units occur in Ethiopia. The mapping units were based on interpretation of knowledge about topography, climate, physiognomy, floristic composition, anthropogenic influences and information from previous geographical and botanical literatures which deals the area. Classifying the farmland with the vegetation of the surrounding, using the term "Savanna" to cover a range of slightly different vegetation type and recognizing wetland vegetation only at Gewane are some of the shortcoming of the map, and most of his thoughts are benchmark for today's vegetation maps of Ethiopia (Zerihun Woldu, 1999 and Friis *et al*., 2011).

2.7.2. Vegetation map of Ethiopia drawn by White (1983)

White (1983) used 80 vegetation units to delimit 22 main phytochoria of Africa and Madagascar. The classification of vegetation type used is primarily physiognomy. In this vegetation map of Africa, the vegetation of Ethiopia falls within four phytochoria or floristic regions (Figure 1). They are

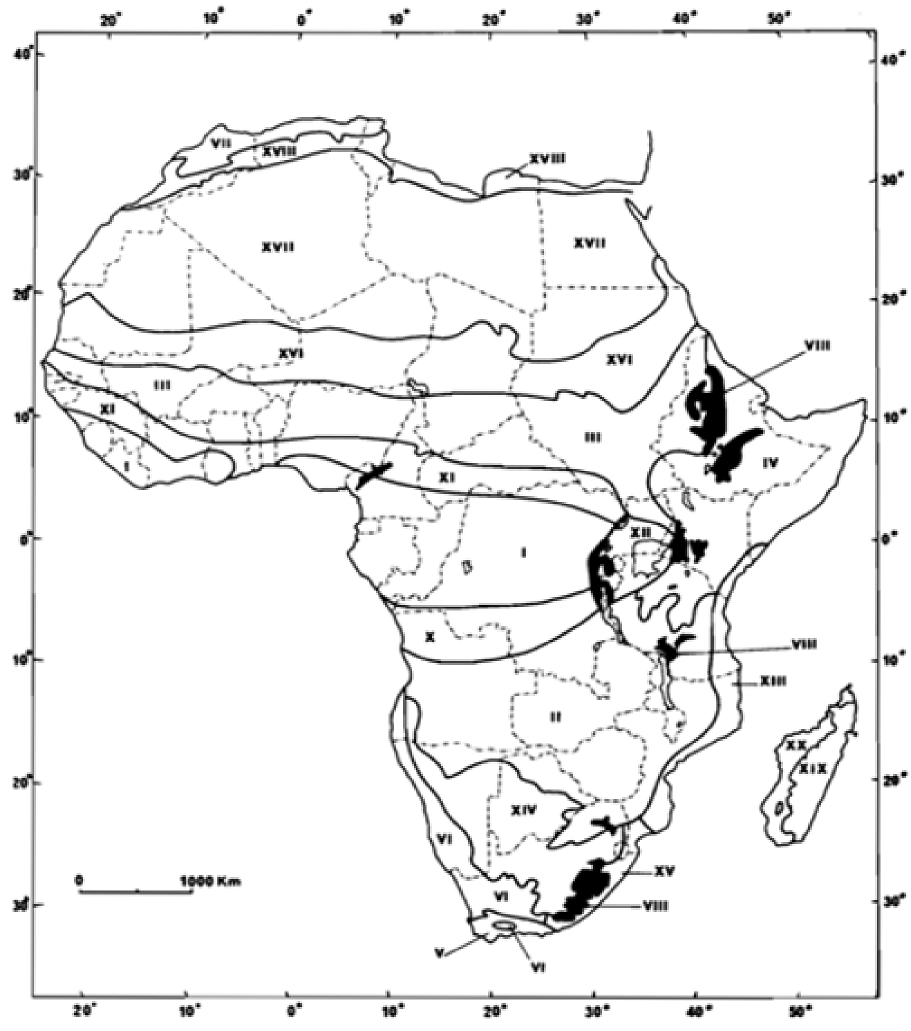

Figure 1. Main phytochoria of Africa and Madagascar (White, 1983)

I: Guineo-Congolian regional centre of endemism. II: Zambezian regional centre of endemism. III: Sudan regional centre of endemism. IV: Somalia-Massi regional centre of endemism. V: Cape regional centre of endemism. VI. Karoo-Namib regional centre of endemism. VII: Mediterranean regional centre of endemism. VIII: Afromontane archipelago-like regional centre of endemism, including IX, Afroalpine archipelago-like regional of extreme floristic impoverishment (not shown separately). X: Guinea- Congolia/Zambezian regional transition zone. XI: Guinea-Congolian/Sudan regional transition zone. XII: Lake Victoria regional mosaic. XIII: Zanzibar-Inhambane regional mosaic. XIV: Kalahari-Highveld regional transitional zone. XV: Toogaland-Pondoland transitional mosaic. XVI: Sahel regional transitional zone. XVII: Sahara regional transitional zone. XVIII: Mediterranean /Sahara regional transitional zone. XIX: East Malagasy regional center of endemism. XX: West regional center of endemism.

1. Sudanian Regional Centre of Endemism (III)

2. Somalia-Massai Regional Centre of Endemism (VII)

3. Afromontane Archipelago-like Regional Centre of Endemism (VIII)

4. Afroalpine Archipelago-like Region of Extreme Floristic Impoverishment (IX)

Friis *et al.* (2011) pointed some errors on the White's Vegetation map of Africa. Phytochoria VIII/XI are distinct from the lowlands and lowland of western escarpment. Phytochrion III is basically different from the eastern escarpment and lowlands of southern and southeast. The exact position of White's vegetation types is often misleading, due to lack of field work and the comparatively imprecise topographical maps.

2.7.3. Vegetation map of Ethiopia drawn by Zerihun Woldu (1999)

On Conservation Strategy Development Workshop (June 1999), Zerihun Woldu presented the following nine broad vegetation types of Ethiopia.

1. *Acacia-Commiphora* woodland
2. Afroalpine and Sub Afroalpine Vegetation

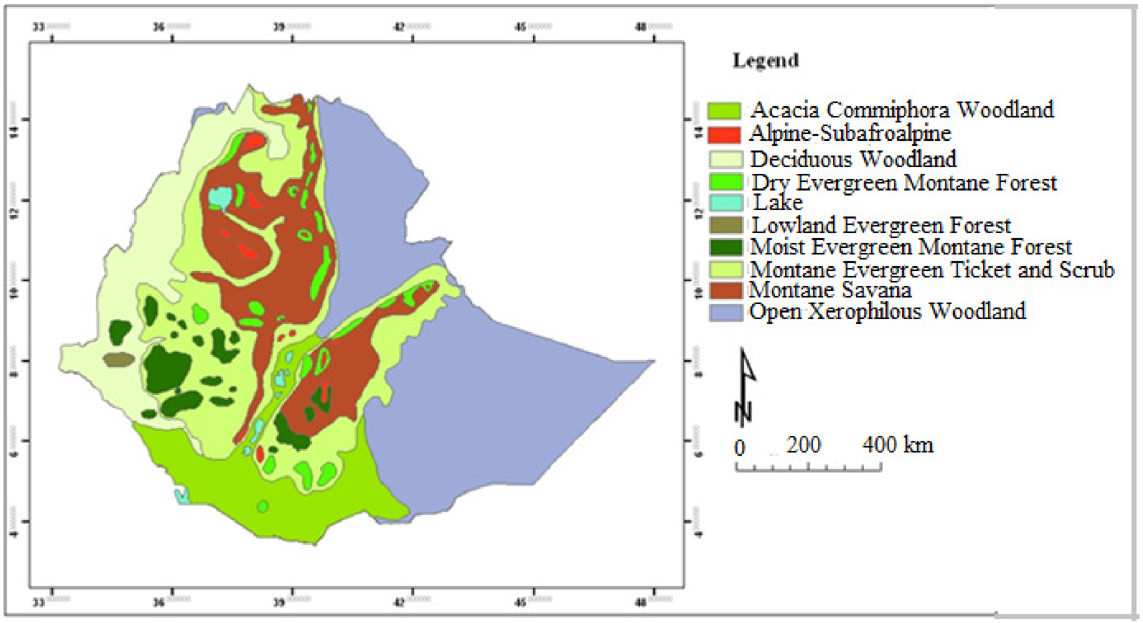

Figure 2. Broad vegetation types of Ethiopia (Zerihun Woldu, 1999)

3. *Combretum – Terminalia* (Broad-leaved deciduous) woodland
4. Dry Evergreen Montane Vegetation
5. Lowland Dry Evergreen Forest
6. Moist Evergreen Montane Forest
7. Montane Savanna
8. Montane Evergreen Thicket Scrub
9. Semi-desert and Desert Open Xerophilous Woodland

2.7.4. Vegetation map of Ethiopia drawn by Friis *et al.* (2011)

Friis *et al.* (2011) have currently recognized 12 major vegetation types of Ethiopia based on information from their previous works, field experience of authors, Flora Of Ethiopia and Eritrea, climatic data (precipitation, temperature, potential evaporation, etc.), soil conditions (chemical composition, texture, pH and salinity), geology of the rock from which the soils have been derived, and GIS technique known as DEMs (Digital Elevation Models). They revised Pichi Sermolli's (1957) and White's (1983) vegetation units and vegetation maps as a bench mark for their work.

1. Desert and Semi-desert scrubland
2. *Acacia-Commiphora* Woodland and bushland
3. Wooded grassland of western Gambell region
4. *Combretum-Terminalia* woodland and wooded grassland
5. Dry evergreen Afromontane forest and grassland complex
6. Moist evergreen Afromontane forest
7. Transitional rainforest
8. Ericaceous belt
9. Afroalpine belt
10. Riverine vegetation
11. Freshwater lakes, lake shores, marshes, swaps and floodplains vegetation
12. Salt-water lakes, lake shores, salt marshes and pan vegetation

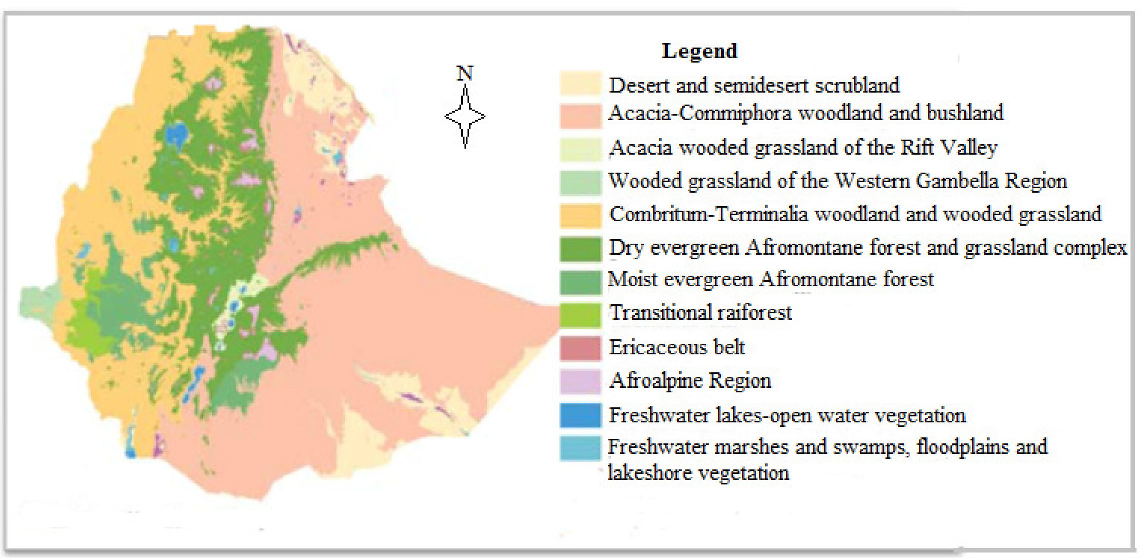

Figure 3. Vegetation types of Ethiopia (Friis *et al.*, 2011)

2.8. Afromontane Vegetation

The Ethiopian highlands are the largest mountain complex comprising over 50% of the African land area covered by Afromontane vegetation (Yalden, 1983; Tamrta Bekele, 1993). The vegetation is a very complex type occurring roughly above 1500 m and below 3200 m in altitude (Zeirhun Woldu, 1999), but according to Friis *et al*. (2011), it is distributed throughout Ethiopian highlands above 1800 m and below 3000 m a.s.l. excluding higher rainfall areas in the western and south-eastern part of the highland where represented by Moist Evergreen Afromontane vegetation type. Typical Dry Evergreen Montane forests such as the Menagesha and Wof-Washa forest are situated on highlands and mountain chains in Ethiopia (Sebsebe Demissew, 1988; Tamrat Bekele 1994).

It is inhabited by the majority of the Ethiopian population and represents a zone of sedentary cereal-based mixed agriculture for centuries (Demel Teketay, 1996). Few large patches still remaining appear widely separated by areas of cultivation and woody grassland, today because agriculture has been practiced in this vegetation type since thousand years ago which resulted in diminishing most of the forests and replacing with grazing-cultivation complex and derived vegetation such as bushland, wooded grassland and grassland in most area (Friis *et al*., 2011). According to Zerihun Woldu (1988), the original climax vegetation on the Montane grassland of Ethiopia was supposed to be a Dry Evergreen Montane forest intermingled with small areas of grassland. This ecosystem has economic, social and cultural values. Economically it is used for crop production, livestock husbandry, construction of thatch roof and making of household crafts. The effect of excessive vegetation harvest, overgrazing, and intensive farming is aggravated by the rugged topography with steep slopes lead to severe soil erosion are main threats to this ecosystem.

Dry Evergreen Montane forest is a part of Afromontane vegetation characterized by a very complex vegetation type and a complex system of succession involving extensive grasslands rich in legumes on heavy black clay soils that are periodically inundated, shrubs, and small to large-size trees to closed forest with canopy of several strata on slops (Friis, 1992; Sebsebe Demissew and Nordal, 2010; Friis *et al*., 2011). Dry Evergreen Montane Forest is multi-storeyed forest vegetation. The top storey consists of a non-uniform, non-compact layer of tall trees. These trees are known as “emergents” because they project above the vegetation mass. Below the layer of emergents there is a mass of shorter trees of various heights. Still lower is a stratum of short trees and large shrubs, much less dense than the second stratum. Finally, there is the lowest stratum of shrubs, suffrutescents, and herbs. Epiphytes, lianas and parasites are common (Zerihun Woldu, 1999).

Tewolde Berhan Gebre Egziabher (1988), for instance, listed plant species that occurred in the Dry Evergreen Afromontane vegetation of Ethiopia. The forests consist mostly of *Juniperus porcera* and *Olea europea* subsp. *cuspidata* as the main trees. Others large trees, including *Acacia abyssinica*, *A. negrii*, *Podocarpus falcatus*, *Olea hochstetteri* and *Apodytes dimidiata*, also occur. Smaller trees include *Allophylus abyssinicus*, *Euphorbia obovalifolia*, *Rapanea simensis*, and *Olinia aequipetala*. Epiphytes including orchids, mosses, and lichens (especially Usnea) are common. The common constituents of the shrub layer are *Discopodium penninervium*, *Myrsine africana*, *Calpurnia aurea*, and *Dovyalis abyssinica*. These strata of vegetation are usually joined by climbers including Smilax spp., *Rubia cordifolia*, *Urera hypselodendron*, *Embelia schimperi*, *Jasminum floribundum*, and various species of the Cucurbitaceae. The ground is covered with grass and various other herbs including ferns and mosses. In the drier and lower parts of the north and east, on the other hand, the complexity of the vegetation is greatly reduced, and there may be only three distinct layers. The upper altitudinal limits also consist of simpler forests of *Hagenia abyssinica* with associated small trees or shrubs of *Hypericum revolutum* and *Rapenea simensis* on deeper soils of the slopes. Stretches of bamboo forest, *Arundinaria alpina*, also occur and its frequency increases towards the west.

The grass species in this ecosystem includes *Pennisetum* spp., *Hyparrhenia* spp., *Eragrostis* spp., *Panicum* spp., *Cymbopogon* spp., *Chloris* spp., *Andropogon* spp. and *Cynodon dactylon.* These various types of grass species are interspersed with trees such as *Acacia abyssinica*, *Prunus africana*, *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, *Allophylus abyssinicus*, *Celtis africana*, *Croton macrostachyus*, *Milletia ferruginea*, *Measa lanceolata*, *Erythrina brucei*, *Myrsine africana*, *Calpurnia aurea*, and *Dovyalis abyssinica*.

Treating Dry Evergreen Montane Vegetation as one vegetation unit is an oversimplification (Zerihun Woldu, 1999). To elucidate well, the Afromontane vegetation of Ethiopia has been classified with different approaches. For instance, Zerihun Woldu (1999) classified the Dry Evergreen Montane Forest into the following five associations. (1) *Mimusops kummel* forests, (2) *Podocarpus falcatus* forest, (3) *Juniperus procera* forest, (4) *Juniperus procera* and *Podocarpus falcatus* forest and (5) *Acacia abyssinica* forest.

Based on floristic composition and few environmental data as a major criteria, Friis (1992); Friis and Sebsebe Demissew (2011) have recognized four distinctive subtypes under Dry Evergreen Afromontane forest and grassland complex: 1. Undifferentiated Afromontane forest: it is characterized by either by *Juniperus-Podocarpus* or towards single dominant *Podocarpus* or *Juniperus* forest which occurs at altitude between 1500 and 2700 m with annual rainfall between 700 and 1100 mm. 2. Dry single-dominant Afromontae forest of the Ethiopian highlands: it is characterized by upper story dominant species of *Juniperus* with *Olea europaea* subsp. *cuspidata* which occurs at altitude between (1600-) 2200 and 3200 (-3300) m with annual rainfall between 500 and 1500 mm. 3. Afromontane woodland, wooded grassland and grassland: the woodland could be primary or secondary. The primary consists mainly of species of *Acacia* such as *Acacia abyssinica, A. lahal, A. nigrii, A. pilsipina, A. origena,* and *A. venosa.* The secondary woodland contains species listed in subtype 1 and 2. 4. Transition between Afromontane vegetation and *Acacia-commiphora* bushsland on the Eastern escarpment: this vegetation type is complex, scattered, rich in endemic species and composed of unusual species which occur at altitude between 1500 and 2400 m annual rainfall between 400 and 700 mm in southeastern slops of the Eastern highlands. Some typical character species are *Barbeya oleoides*, *Cadia purpurea*, *Pistacia aetopia* are unusual species. *Acokanthera* *schimperi*, *Tarchonanthus camphorates*, *Sideroxylon oxyacntha*, *Olea europaea* subsp. c*uspidata* and *Schrebera alata* are also character species.

2.9. Afroalpine Vegetation

According to App *et al*. (2008) and Friis *et al*. (2011), higher than 3,200 m a. s. l. in average are generally referred to as the Afroalpine and Sub-Afroalpine. The lower limit of the Afroalpine belt falls at about 3,500 meters, while the upper limit of vascular plants lies around 5,000 meters and sub-Afroalpine areas ranges between 3,200 and 3,500 meters. These areas include chains of mountains, mountain slopes, and tops of the highest mountains in the country. The highest peak in Ethiopia is Ras Degen, where an alpine climate near 0°C persists year-round, sometimes with a snow cover lasting a couple of days. In general, Ethiopia has the largest extent of Afroalpine habitats in Africa. According to Friis *et al*. (2011), Afroalpine vegetation occupies the high mountain in the country and the lower zones of Afroalpine belt (Sub-Afroalpine or Ericaceous) are characterized by small trees, shrubs and shrubby herbs such as *Erica arborea, Erica trimera, Hypericum revolutum* and *Myrsine melanophloeos*. The upper zones are characterized by giant herbs, small herbs and grasses, for example, *Alchemilla haumannii, Geranium arabicum, Anthemis tigreensis, Haplocarpha rueppellii, Helichrysum citrispinum, H. splendidum, H. gofense, H. formosissimum, Senecio schultzii, Romulea fiscneri, Satureja biflora, Thymus schimperi* and *Trifolium acaule*. Ferns like genus *Polysticnum*, *Aloe steudneri, Kniphofia foliosa* and *Permula verticillata* are also common plants in this vegetation type.

Tewolde Berhan (1988) described the distribution and environmental relation of Afroalpine vegetations as the following. "On slopes where water does not collect, the vegetation consists of meadow grasses (e.g., *Festuca schimperiana*), other herbs (e.g., *Trifolium acaule*), and small species of Lobelia, *Luzula abyssinica*, *Alchemilla* spp., and *Thymus serrulatus* with scattered patches of *Lobelia rhynchopetalum*. Cushions of *Helichrysum citrispinum* and even shrubs of *Erica arborea* together with various herbs (e.g., *Arabis alpina*, *Epilobium* spp.) occur on the steeper slopes. On the flatter ground where water may be ponded aquatic species occur (e.g., *Ranunculus* spp., *Veronia* spp., and various Cyperaceae and Juncaceae). On rocky outcrops where soil is found in crevices (fissure) various herbs grow (e.g., *Afrovivella simnsis*, *Oreophyton falcatum*, and *Arabis alpina*). Various mosses and lichens also occur. At lower altitudes in the Sub-Afro-alpine, the most extensive vegetation is of ericaceous scrub, consisting of *Erica arborea* Originally, this scrub formed a woodland since, left unburnt; both *E. arborea*. On slopes the ericaceous scrub grows on very thin soil, and often there is practically no soil under the decaying plant remains. Conditions for plant growth, especially soil temperature, are more favourable here than at higher altitudes in the Afroalpine. However, the conditions are still poor and *E. arborea* is an indicator of unfavourable conditions at lower altitudes. The areas of deeper soil in the Subafro-alpine belt support more species of woody plant (e.g., *Hypericum revolutum, Gnidia glauca*, and *Rapanea simensis*) and on the deepest well-drained soils at the lower altitudinal limit there are *Hagenia abyssinica* trees as well as many species of herb. The poorly drained flatter areas support meadows (grass field) and marsh or aquatic vegetation. The soil here is often thin, although very rich in undecomposed organic matter with peat accumulating in many places".

2.10. Plant Colonization, adaptation and endemism on the high mountains of Ethiopia

There are some hypotheses when and how high mountains of Ethiopia were colonized with vegetation. The mountains have evidently stood isolated from each other since their origin, and dispersal of plants between them must presumably have occurred mainly by long distance transport, possibly facilitated by cyclones (Hedberg, 1969). The closest relatives of most of the Afroalpine plant are found in distant parts of the world, such as in the Mediterranean, than in the lower parts of the mountain (Hedberg, 1965). This suggests that the Afroalpine plants are complex derivatives and most of the mountains harboring them are of volcanic origin and of unequal ages (Miocene to late Pleistocene) (Hedberg, 1970). According to Kingdon, (1989), during the last Ice Age (Pleistocene climate), the higher areas of the Ethiopian Plateau were glaciated and surrounding areas were covered with Afromontane vegetation resembling the Eurasian tundra. As the climate warmed the broad belts of sub-alpine vegetation contracted, and became restricted to higher altitudes. The ice cover on the peaks of these highlands retreated only a few thousand years ago; therefore, vegetation has only relatively recently colonized these areas.

Ecologically, the Afroalpine biota is indeed an island biota. The high mountain summits protrude as isolated temperate islands above the warm surrounding plains (Hedberg, 1961). The isolation of these high mountains provides unique opportunities speciation in connection with geographical isolation and adaptation to extreme environmental conditions (Hedberg, 1975). Plant life at these high elevations is primarily constrained by direct and indirect effects of low temperatures, radiation, wind and storminess or insufficient water availability (Körner and Larcher, 1988). Plants respond to these climatological influences through a number of morphological and physiological adjustments such as stunted growth forms and small leaves, low thermal requirements for basic life functions, and reproductive strategies that avoid the risk associated with early life phases (Beniston, 2003).

The climate of the Afroalpine belt is rather harsh, with 'summer every day and winter every night', and its flora is poor in species. This Afroalpine flora is, however, extremely interesting because of the striking ecological adaptations displayed by many species (Hedberg, 1964). According to Tewolde Brehan (1988), high altitude means that the plants are exposed to intense radiation, and hence a much greater rise in the temperature of their aerial parts in contrast to the underground parts. Transpiration is thus high compared to water absorption into the plant. The plants, therefore, are mostly adapted to conditions of drought in spite of the high soil moisture. For example, many of them are succulent (e.g., *Kniphofia* spp., *Bartsia petitiana*, *Crassula* spp., *Aeonium leucoblepharum*); some are cushion-forming in order to minimize exposed surfaces; and some are even spinescent (e.g., *Helichrysum citrispinum*). The plants are also slow growing and of low stature; the aerial parts at or just above ground level often prostrate (e.g., *Helichrysum* spp., *Alchemilla* spp.). *Lobelia rhynchopetalum*, however, grows to over 2 m in height; the question of how this plant solves the problem of water stress would make a very interesting study.

Plant populations that occupy latitudinal and elevational climatic gradients usually exhibit clines in morphology in addition to phenology and physiology (Jonas and Geber, 1999; Clevering *et al*., 2001). On the other hand, patterns of species distribution and species richness have been determined by environmental factors along altitude. Thus, characteristically, the vegetation of high mountains deviates very much from that of the intervening lower country ('geographical isolation'), displaying a marked zonation with an Afroalpine belt, a subalpine (ericaceous) belt and a Montane forest belt (Hedberg, 1951).

Some 80% of the Afroalpine species of vascular plants are endemic to the high mountains of east Africa and Ethiopia (Hedberg, 1961). Ethiopia is an important regional center of biological diversity, and the flora and fauna have a rich endemic element (Sayer *et al.*, 1992). Endemism is particularly high in the Afroalpine vegetation zone, Dry Montane forest and grassland complex of the plateau (Sebsebe Demissew *et al*., 1996). The occurrence of variety of flora and endemism in Afroalpine and Afromontane belts have been the result of adaptations to harsh environment such as elevational climatic gradients (like intense radiation, high transpiration, greater rise in the temperature of their aerial parts in contrast to the underground parts) could lead to evolutionary change due to natural selection and drift (Hedberg, 1986; EPA and MEDAC, 1997). However, the vegetation has very slow growth rate decrease in size or height from the lower slopes to the summit (White, 1983; Hedberg, 1965). But the percentage of endemics is much higher among those taxa, which are restricted to high levels than among those occurring at lower level (Hedberg, 1986). Huntley (1988) has also advocated that the Afromontane region is one of the seven centers of endemism of the Afrotropical realm.

2.11. Biodiversity

Biodiversity is defined by the CBD (1992) as "the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems".

Main terms associated with diversity are defines by Colwell (2009) as Diversity index*:* a mathematical expression that combines species richness and evenness as a measure of diversity; evenness: a measure of the homogeneity of abundances in a sample or a community; functional diversity: the variety and number of species that fulfill different functional roles in a community or ecosystem; relative abundance: the quantitative pattern of rarity and commonness among species in a sample or a community; richness estimator: a statistical estimate of the true species richness of a community or larger sampling universe, including unobserved species, based on sample data; species accumulation curve: the observed number of species in a survey or collection as a function of the accumulated number of individuals or samples; species–area relation: the generally decelerating but ever-increasing number of species as sampling area increases; species richness: the number of species in a community, in a landscape or marinescape, or in a region; α-diversity: species diversity (or richness) of a local community or habitat; β-diversity: the difference in diversity associated with differences in habitat or spatial scale; γ-diversity: the total diversity of a region or other spatial unit.

Zerihun Woldu (in press) described Beta diversity as the following. It is the rate of change of community along an ecological gradient and thus, it measures the change in diversity of species among set of communities by calculating the number of species that are not the same in two the communities. A high β–diversity index indicates a low level of similarity, while a low beta diversity index shows a high level of similarity.

Shannon and Weaver index (H′) has probably been the most widely used index in community ecology. It is based on information theory (Shannon and weaver, 1949), and is a measure of the average degree of uncertainty in predicting to what species an individual chosen at random from a collection of S species and N individuals will belong.

Although there are many others, the most commonly used diversity indices in ecology are Shannon and Weaver diversity, Simpson diversity, and Fisher's α (Colwell, 2009), however, Shannon and Weaver index (H′) has probably been the most commonly used index in community Ecology (Colwell, 2009; Zerihun Woldu, in press).

The Shannon and Weaver Index takes both species richness and the relative abundance of each of these species in a community into account to determine the uncertainty that an individual picked at random will be of a given species (see the equation in section 4.7).

Biologically realistic H′ values range from 0 (where there is only one species in the sample) to about 4.5 (high uncertainty as species are relatively evenly distributed or when all species are represented by the same number of individuals) (Zerihun Woldu, in press). According to Kent and Coker (1992), the Shannon and Weaverr diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5.

Evenness (J) is an index that makes the H′ values comparable between communities by controlling for the number of species found within the communities (see the equation in section 4.7). J can range from close to 0, where most species are rare and just a few are abundant, to 1, where the potential evenness between species (H′max) is equal to that which was observed (H′).

2.12. Vegetation and plant community

Vegetation can be loosely defined as a system of largely spontaneously growing plants, while vegetation ecology (synecology) is the study of the plant cover and its relationships with the environment (van der Maarel, 2005). Westhoff and van der Maarel (1978) proposed to reserve the term ‘phytocoenose’ for the concrete stand of vegetation. Their definition may be reformulated as ‘a piece of vegetation in a uniform environment with a relatively uniform floristic composition and structure that is distinct from the surrounding vegetation’ (van der Maarel, 2005). Alternatively, J. Braun-Blanquet strongly emphasized on typology, the establishment of plant community types based on descriptions of stands (called relevés). Based on relevés, he could establish plant community types (van der Maarel, 2005).

Two conceptual approaches (debates) dominated about community organization prior to the 1950s: the Community-unit concept or Holistic view point associated with its proponent F.E. Clements, and the Individualistic Concept or Continuum associated with primarily on the idea of H.A. Gleason, (Whittaker, 1962; Mueller-Dombois and Ellenberg 1974; Westhoff and van der Maarel, 1978).

Community-unit concept states that communities are distinct spatial entities and developed with one super-organism complex giving way to another (either in space or time). The community-unit concept claims that when species distribution are plotted along some gradient or gradient-complex whose rate of change is constant, there exist group of species, i.e., 'communities' which replaces themselves along the chosen gradient (Whittaker, 1975). Within each group most species have similar distribution and the end of the group coincides with the beginning of another (Shipley and Keddy, 1987).

The individualistic concept states that 'centers and boundaries of species' distribution are scattered along the environmental gradient (Whittaker, 1975). No distinct groups of species are predicted to exist therefore precluding the coincidence of one group with another (Shipley and Keddy, 1987).

Shipley and Keddy (1987) simplified the controversy by reducing it to the occurrence of different boundary patterns in the field. They devised a field method to test the 'individualistic and community-unit concepts as falsifiable hypotheses'. They detected the concentration of species distribution boundaries at certain points along environmental gradients.

It is thus quite possible to arrive at plant community types by comparing phytocoenoses which may lack sharp boundaries – or/and floristic uniformity – but which appear to be sufficiently similar (van der Maarel, 2005).

2.13. Multivariate analysis

Multivariate analysis provides statistical methods for study of the joint relationships of variables in data that contain inter-correlations. Because several variables can be considered simultaneously, interpretations can be made that are not possible with univariate statistics (James and McCulloch, 1990). Vegetation Ecology entertains two kinds of multivariate data analyses. The first set of analyses categorized under Cluster Analysis is run on both rectangular and arbitrary dissimilarity matrices. These include hierarchical and partitioning techniques. The second set of multivariate analysis includes data representation methods categorized under Indirect Ordination and Direct Ordination (Gradient Analysis) (Zerihun Woldu, in press). In brief, Cluster analysis (Classification) is the placement of species and/or sample units into groups, and ordination is the arrangement or 'ordering' of species and/or sample units along gradients (Palmer, 2006).

2.13.1. Cluster analysis in vegetation ecology

Differences in species composition of a community are caused either by internal processes within the community, such as dispersal and competition (false gradients), or as a response to external factors, such as environmental variation (true gradients) (Legendre, 1993). Population dynamics and interspecific interactions operate through individual organisms that exist and interact only within their immediate neighborhood (Tilman and Kareiva, 1997). Such contagious biotic processes create ‘‘spatial autocorrelation’’ within the community (Legendre, 1993). On the other hand, physical processes create spatial structure in environmental factors, which in turn causes ‘‘spatial dependence’’ in biotic communities (Legendre, 1993; Legendre and Legendre 1998). These factors cause structure of biotic communities (Legendre, 1993). In cluster analysis, objects are placed in groups according to a similarity measure and then a grouping algorithm (James and McCulloch, 1990). In ecology and systematics, the general term "cluster analysis" usually means agglomerative hierarchical cluster analysis. This is a set of methods that starts with a pair-wise similarity matrix among objects (individuals, sites, populations and taxa). The two most similar objects are joined into a group, and the similarities of this group to all other units are calculated. Repeatedly the two closest groups are combined until only a single group remains. The results are usually expressed in a dendrogram, a two-dimensional hierarchical tree diagram representing the complex multivariate relationships among the objects or variables (James and McCulloch, 1990). According to James and McCulloch (1990), cluster analysis is most appropriate for categorical rather than continuous data.

2.13.2. Ordination in vegetation Ecology

Ordering data of vegetation is a collective term for multivariate techniques aimed at arranging samples (relevès) according to their specific structure (ter Braak and Tongeren, 1995), a process of representation as true relations between samples of vegetation, species and environmental factors in the reduced dimensional space of several axes (usually 2 to 3 axis) (Tănase, 2012). According to Gauch (1982), "Ordination primarily endeavours to represent sample and species relationships as faithfully as possible in a low-dimensional space".

The relative position of a specie, relevè, or association, can be described as a function of environmental factors registered for direct analysis of gradients, or they can be positioned along the imaginary axis and can be interpreted as an ecological gradient, registering the analysis of indirect gradients (Cristea *et al*., 2004). Environmental gradients are plotted as vectors, whose length is proportional to the amplitude factor that they produce and can be interpreted in conjunction with species or relevès (Tănase, 2012).

Indirect ordination describes intrinsic gradients in species composition, while direct ordination identifies compositional gradients in a community as a response to measured environmental factors (De'ath, 1999). Indirect gradient analysis utilizes only the species data whereas direct gradient analysis, in contrast, utilizes environmental data in addition to the species data. Indirect gradient analysis or unconstrained ordination (eigenanalysis based) includes *Linear model* such as Principal Components Analysis (PCA); *Unimodal model* such as Correspondence Analysis (CA) and Detrended Correspondence Analysis (DCA). Direct gradient analysis or constrained ordination includes *Linear model* such as Redundancy Analysis (RDA); *Unimodal model* such as Canonical Correspondence Analysis (CCA), and Detrended Canonical Correspondence Analysis (DCCA) (Palmer, 2006).

2.14. Physical and chemical factors of soil

2.14.1. Soil texture

Determination of the particle-size distribution in a soil sample is one of the most fundamental procedures in soil science (Lindbo *et al*., 2008). Soil texture refers to the proportion of the various particle-size classes (sand, silt and clay) in a given soil volume and the names of the textural classes are most frequently determined by the USDA Soil Textural Triangle (FAO, 2006).

Sand, silt and clay particles have diameter of 0.05 to 2 mm, 0.05 to 0.002 mm and less than 0.05 mm, respectively. Generally, clay soils have more than 40% clay particles, whereas sandy soils have more than 55% sand particles. Loamy soils have percentage of sand silt and clay in right proportion so that the influence of particles is equal (Wildman and Gowmans, 1978 cited in O'Geen, 2006).

O'Geen (2006) noted that Soil texture is an important property controlling soil erodibility. Soils with a high content of silt tend to have high erodibility. Medium-textured soils (loamy soil) tend to be most erodible because they have high amount of silt and fines sands. These soils tend to have moderate to low permeability and low resistance to particle determinant. Erodibility is low for clay-rich soils because the clay particles mass together into large aggregates that resist detachment and transport. Sandy soil with high amount of fine, medium or coarse sand particles also have low erodibility and the sand particles lack the ability to aggregate together. Since most sandy soil are highly permeable, water runoff is low and hence erosion is often slight. In addition, the larger size of sandy soil means that it takes more energy to transport its particles than those of finer-textured soils.

Brown (2003) reckoned the that fine-textured soils generally are more fertile, contain more organic matter, have higher cation exchange and buffer capacities, are better able to retain moisture and nutrients, and permit less rapid movement of air and water. Soils having sandy loam or loam-textured surface are better suited for most plants. On contrary, sandy soils tend to be low in organic matter content, low in ability to retain moisture and nutrients, low in cation exchange and buffer capacities, and rapidly permeable water and air.

2.14.2. Soil pH

Soil pH, by definition, is a measure of the activity of hydrogen ions in the soil solution (FAO, 2006) or it is the negative log of the hydrogen ions activity. The pH range normally found in soils varies from 3 to 9. Various categories of pH may be arbitrarily described as follow: Strong acid (pH < 5.0), moderately to slightly acid (5.0-6.5), neutral (6.5-7.5), moderately alkaline (7.5-8.5) and strongly alkaline (pH > 8.5) (Londo *et al*., 2006; FAO, 1980). Soil pH affects the availability of mineral nutrients to plants as well as many soil processes (FAO, 2006), i.e., the availability of many plant nutrients in the soil changes as a result of reactions in the soil, which are largely controlled by soil pH. Soils with a pH of 6.0-7.0 typically have high concentrations of available nutrients (Williston and LaFayette 1978 cited in Londo *et al*., 2006). Extremes in soil pH (< 4.5

and > 8.5) can make some nutrients toxic and others unavailable to plants. At low pH levels (< 4.5), aluminum, iron, and manganese are very available for plant uptake. At high pH levels (> 7.5), calcium and potassium are over abundant (Londo *et al*., 2006).

2.14.3. Electric conductivity and salinity of soil

The term soil salinity refers to the concentration of the major dissolved inorganic solutes in soils. It is normally measured by extracting the soil sample with water (1:1 or 1:5) soil water ratio or in a saturated paste extract. The electrical conductivity of the extract (EC) is commonly used as an expression of the total dissolved salt concentration of an aqueous sample of soils (essentially, Na^+, Mg^{++}, Ca^{++}, K^+, Cl^-, $SO_4^=$, HCO_3^-, $NO3^-$ and $CO3^=$) because EC and total salt concentration of an aqueous solution are closely related, i.e., salinity is quantified in terms of the total concentration of soluble salts, or more practically, in terms of the electrical conductivity of the solution (FAO, 1999). The determination of EC generally involves the physical measurement of the materials' electrical resistance (R), which is expressed in ohms. Electrical conductivity has been customarily reported in micro-mhos per centimeter (μmho/cm), or in milli-mhos per centimetre (mmho/cm) (FAO, 1999).

2.15. Structure

Importance value (IV) is defined as the sum of relative density, relative frequency and relative dominance (relative basal area) (Muller-Domboise and Ellenberg, 1974). High density and high frequency with high BA indicate the overall dominance of a species in the forest (Lamprecht, 1989). IVI is used for setting priority of ranking species management and conservation practices and help to identify their sociological status in a certain plant community as dominant or rare species (Kent and Coker, 1992).

CHAPTER THREE

3. Study area

3.1. Choke Mountain range

Choke Mountain range is located in East Gojjam, Northwest Ethiopia, approximately 332 km Northwest of Addis Ababa.

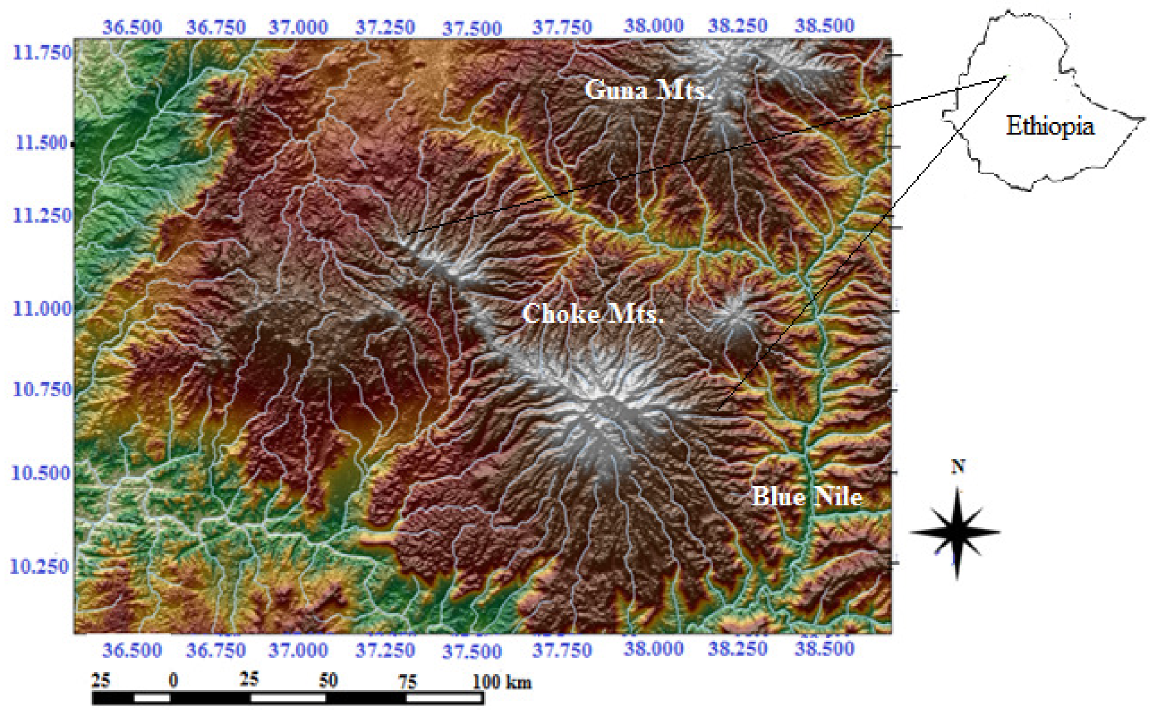

Figure 4. Location map of study area in Choke Mountain range

The study area in these mountain range extends $10^{0}34'$ to $10^{0}46'$N latitude and $37^{0}47'$ to $38^{0}01'$E longitude, covering approximately 540.82 sq. km (54082 ha). This study area was totally situated in the Afroalpine belt, at altitudinal range between 3430 m (the edge of farmlands) and 4080 m (the higest peak of the mountain) and its terrain drains into Abay (Blue Nile).

Figure 5. Partial view of Choke Mountain range (Photo: Getaneh Belachew, 2012)

3.1.1. Climate of Choke Mountain range

Digua Tsion is a small town in the Choke Mountain range where a meteorological station is found. The town is the center of ‘Bibugn woreda’ in East Gojjam, located at 11^{0}00N, 37^{0}35E. The climatic data, which had been recorded at station, were obtained from National Metrological Agency of Ethiopia. The data was analyzed and diagrammatically depicted as the following.

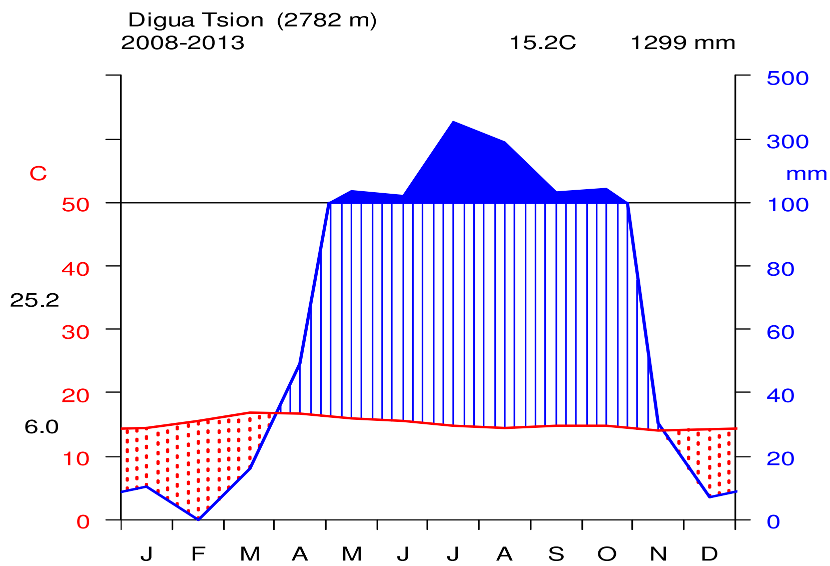

Figure 6. Climatic diagram of Digua Tsion

Annual migration of the Intertropical Convergence Zone (ITCZ) is the main factor that determines the pattern of unimodal precipitation on Choke Mountain range (see section 2.7.2). Most rain falls during May–October rainy season (kiremt). The distribution of precipitation across the mountains is not uniform; the western slopes tend to be wetter than the eastern slopes (Belay Simane *et al*., 2013). Based on Mean annual rainfall from the Tropical Rainfall Measurement Mission (TRMM) satellite, product 3B42Mean, Belay Simane *et al*. (2013) determined that the mean annual rainfall of Choke mountain range is 600-1600 mm (Figure 7A). Mean annual rainfall of western slopes and summit are ca. 1600 mm and 1000 mm, respectively.

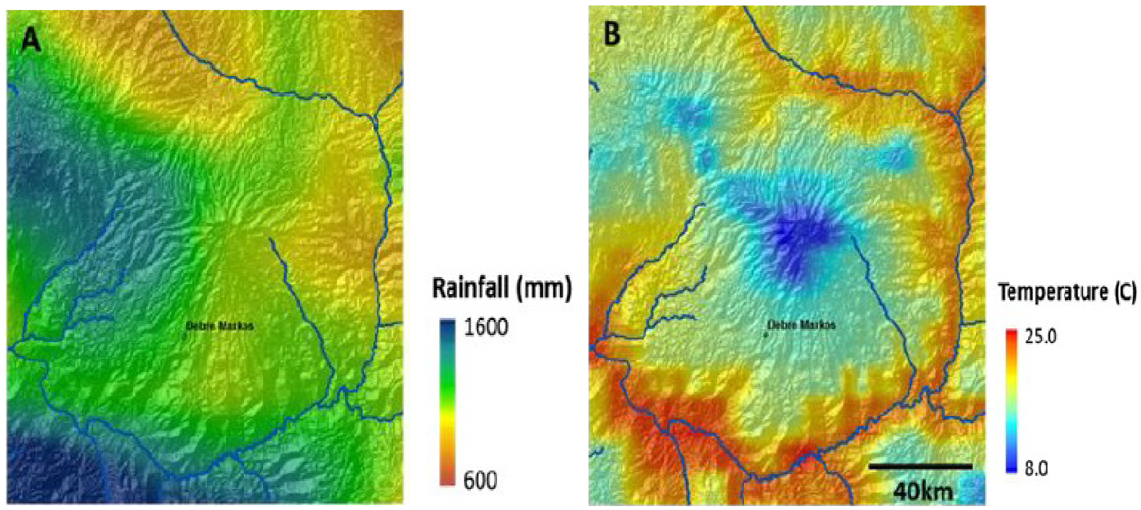

Figure 7. Mean annual rainfall and temperature of Choke Mountain range

(**A**) Mean annual rainfall from the Tropical Rainfall Measurement Mission (TRMM) satellite, product 3B42; (**B**) Mean annual temperature downscaled from Global Data Assimilation System (Source: Belay Simane *et al*., 2013)

3.1.2. Temperature of Choke Mountain range

Based on Mean annual temperature downscaled from Global Data Assimilation System, Belay Simane *et al*. (2013) could also determine the mean annual temperature of Choke Mountains (Figure 7B), including its peak ranges 12-8^{0}C.

3.1.3. Geology of Choke Mountain range

Shield-volcano–building episodes gave rise to the development of Choke volcanoes in Mio-Pliocene of Cenozoic Era. The rocks, the major part of which is basaltic, have considerable thickness, reaching a maximum of 3000 to 3500 m (Alebachew Beyene and Abdelsalam, 2005). Prevailing soil types of Choke Mountains are volcanic in origin, derived from Mio-Pliocene shield volcano lavas and, at lower elevations, Oligocene flood basalts (McCarthy, 2001 cited in Belay Simane *et al*., 2013). Alisols, Vertisols, Cambisols, Luvisols, Nitosols, Leptosols and Fluvisols are the dominant soil types of choke mountains (Belay Simane *et al*., 2013) (Figure 8).

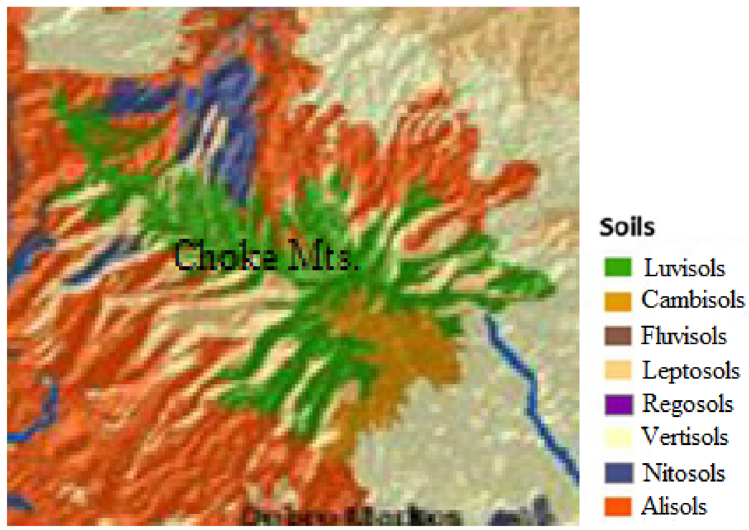

Figure 8. Dominant soil types of Choke Mountain range (From the FAO global soil map, nominally at scale 1:5,000,000; Source: Belay Simane *et al*, 2013)

3.1.4. Threats to Choke Mountain range

The natural vegetation is under intense pressure from population due to demand for farmland, grazing land and fuel wood. Erosion-inducing traditional farming has extended up to 3800 m and over grazing is almost everywhere on the mountain except some protected areas. In addition, cutting of *Erica arborea* for fuel wood and constructing (fence and house) as well as cutting of leafy branches of *Hypericum revolutum* for fodder are also major factors that affect the natural vegetation of Choke Mountains range.

3.2. Kurub, Chung, kasakan, Guble and Darken Mountain Forests

Kurub, Chung, Kasakan, Guble and Darken Mountain Forests are found in Awi zone, West Gojjam, Northwest Ethiopia. Koso Ber, capital of the zone, is the nearest town to the forest and it is located 437 km northwest of Addis Ababa.

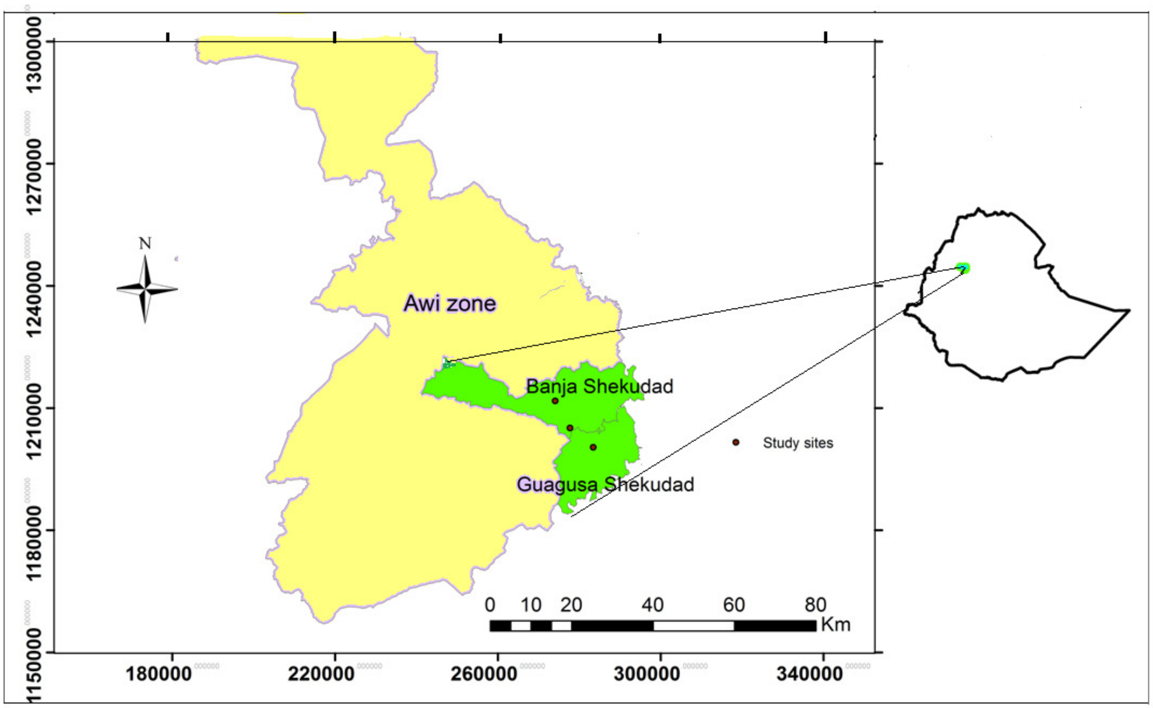

Figure 9. Location map of study areas in Awi zone, West Gojjam

Based the classification criteria of Zerihun Woldu (1999) and Friis *et al.* (2011), these Mountain Forests are categorized under Dry Evergreen Afromontane fores (see section 2.9). The forests are surrounded by grazing and farmlands which are being gradually expanded to the gentler slopes where the forest is situated.

3.2.1. Kurub, Chung and Kasakan Mountain Forests

Kurub, Chung and Kasakan Forests are located nearly 421 km northwest of Addis Ababa. These intact mountain forests extend between $10^0$49'46.66'' N and $10^0$50'25.10'' N latitude and $37^0$01'48.91'' E to$37^0$02'44.84'' E longitude, covering approximately 189 ha. Tilili is the nearest town which is located approximately 1.5 km northwest of the forests. Kurub, Chung and Kasakan are situated between altitudinal range of 2527 and 2670m, 2555 and 2730 m, and 2520 and 2613 m, respectively.

Figure 10. From left to right: Partial view of Kurub, Chung and Kasakan Mountain Forests (Photo: Getaneh Belachew, 2012)

Figure 11. Partial view of Kurub Mountain Forest (Photo: Getaneh Belachew, 2012)

Figure 12. Partial view of Chung Mountain Forest (Photo: Getaneh Belachew, 2012)

Figure 13. Partial view of Kasakan Mountain Forest (Photo: Getaneh Belachew, 2012)

3.2.2. Guble Mountain Forest

Guble Mountain Forest is located at $10^0$53’96.74” N, $36^0$57’45.07’’E, nearly 429 km northwest of Addis Ababa. Kessa is the nearest small town which is located approximately 1 km east of the forest. The forest is situated between 2480 and 2658 m a.s.l., covering approximately 33 ha of the mountain. There are several stumps and a seasonal pond at eastern bottom of the forest. Several footpaths of cattle were commonly seen inside the forest.

Figure 14. Partial view of Guble Mountain Forest and seasonal pond beneath the mountain (Photo: Getaneh Belachew, 2012)

3.2.3. Darken Mountain Forest

Darken Mountain Forest is located at $10^0$55'32.27'' N, $36^0$56'39.87 E, almost 437 km northwest of Addis Ababa. The forest is situated between 2520 and 2721 m a.s.l., covering approximately 49 ha of the dome-shaped mountain. Koso Ber is the nearest town which is located approximately 4.2 km northwest of the forest.

Figure 15. Partial view of Darken Mountain Forest (Photo: Getaneh Belachew, 2012; from Ca. 200m distance)

3.3. Climate of Gundil

The nearest meteorological station to the Kurub, Kasakan, Chung, Guble and Darken Mountain forests is located at Gundil. Its geographical location is 37^{0}25E, 10^{0}57N. Annual migration of the Intertropical Convergence Zone (ITCZ) is the main factor that determines the pattern of unimodal precipitation on Kurub, Chung, Kasakan, Guble and Darken Mountains (see section 2.7.2). Based on the annual rainfall distribution patterns, the rainfall regimes of these mountains are characterized by mono-modal rainfall known as ‘Kiremt’ (a rainy season which occurs from May to October (Tesfaye Haile and Yarotskaya, 1987; Tamiru Alemayehu, 2006).

The climatic data, which had been recorded at Gundi, were obtained from National Metrological Agency of Ethiopia. The data was analyzed and diagrammatically depicted as the following.

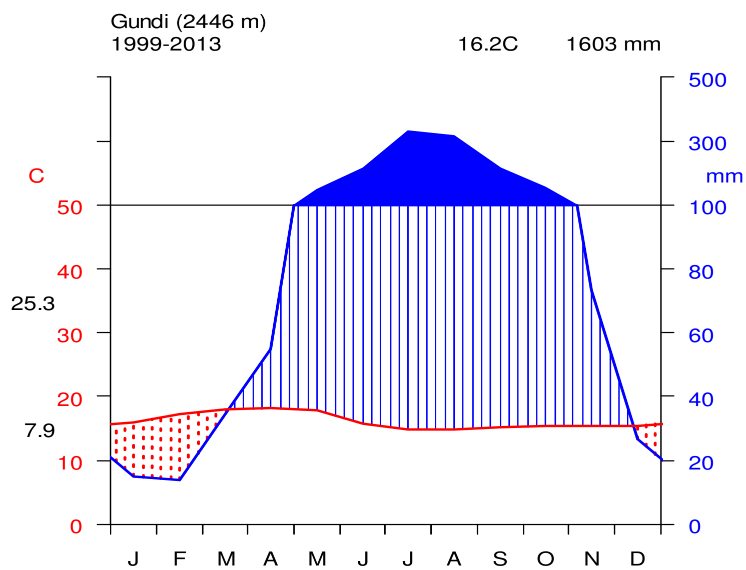

Figure 16. Climatic diagram of Gundil

3.4. Geology of Kurub, Chung, Kasakan, Guble and Darken Mountains

The mountains are the result of volcanic eruption, occurring in Tertiary to Quaternary periods (Mohr, 1971). They consist of volcano rocks including rhyolites, trachytes, tuffs, ignimbrites, agglomerates, and basalts (Alebachew Beyene and Abdelsalam, 2005). As it is seen on soil map of world (http://www.fao,org/) the dominant soil type in the Awi zone, where these mountains are found, is Fluvisol.

CHAPTER FOUR

4. Methodology

4.1. Reconnaissance survey and field data collection

A reconnaissance survey of the study area was conducted in the first two weeks of September, 2011 to get impression on the general topographic feature and vegetation physiognomy, and to decide sampling method. Actual Field data collection was carried out between September, 2011 to December, 2011 and September, 2012 to December 2012.

4.2. Sampling design

A systematic sampling design was used to collect vegetation and environmental data (Mueller-Domboise and Ellenberg, 1974; Kent and Coker, 1992; Krebs, 1989; McCune and Grace, 2002). Based on the concept of minimal area (Kent and Coker 1992), a total of 212 (8.48 ha) sample plots each with a size of 20 m x 20 m (0.04 ha) were systematically laid at 25 m altitudinal intervals along 8 transect lines on Choke Mountains and 18 transect lines on five other outcropped Mountains (Kurub, Chung, Kasakan, Guble and Darken).

The interval between two transects was 1500 m at base of the Choke Mountains, and all the transect lines were extended from the edge of farmlands to summits. At each of 25 m altitudinal gradient, additional plots were preferentially laid within two neighboring transects where different homogeneous stands were visually seen.

In the case of Kurub, Chung, Kasakan, Guble and Darken Mountains, transects were laid on the East, South, West and North faces of the mountains. The interval between two transects was 300 m at the base of the mountain, due to its relative small size. At each of 25 m altitudinal gradient, additional plots were also preferentially laid within two neighboring transects where different homogeneous stands were visually seen.

4.3. Vegetation data collection

4.3.1. Woody plant species data collection

All woody plant species were recorded in 20 m × 20 m plot. Height and circumference at breast height (CBH) were measured for each woody plant species that had height ≥ 2.5 m and CBH ≥ 7.85 cm. The height was measured using a Clinometer (Clino Master) in open forest and a calibrated bamboo stick in dense forest, whereas the circumferences were measured using a strap meter. The circumferences were converted to DBH (diameter at breast height) using the formula, $C = 2\pi r$. Percentage aerial cover-abundance of each woody species was visually estimated and rated based on 1-9 scale of Braun-Blanquet (as modified by van der Maarel, 1979): 1-3 individuals=1; Few individuals or (0.5-1.5 %] = 2; (1.5-3 %] = 3; (3-5 %] =4; (5-12.5 %] = 5; (12.5-25 %] = 6; (25-50 %] = 7; (50-75 %] = 8; (75-100 %] = 9

4.3.2. Sapling and seedling data collection

Individuals attaining 150 cm and above in height but less than 10 cm thick were considered as sapling. Following Tadesse Woldemariam (2003), five subplots (3m x 3m) were laid at the four corners and center of the main sample plot to count sapling and seedling of all tree and shrub/tree species (Figure 17).

4.3.3. Herbaceous data collection

Five small sub plots (1m x 1m) were delimited at four corners and the middle of a sample plot in order to collect soil samples and record herbaceous data. Cover abundance of each herbaceous plant species was visually estimated and rated based on 1-9 scale of Braun-Blanquet (as modified by van der Maarel, 1979).

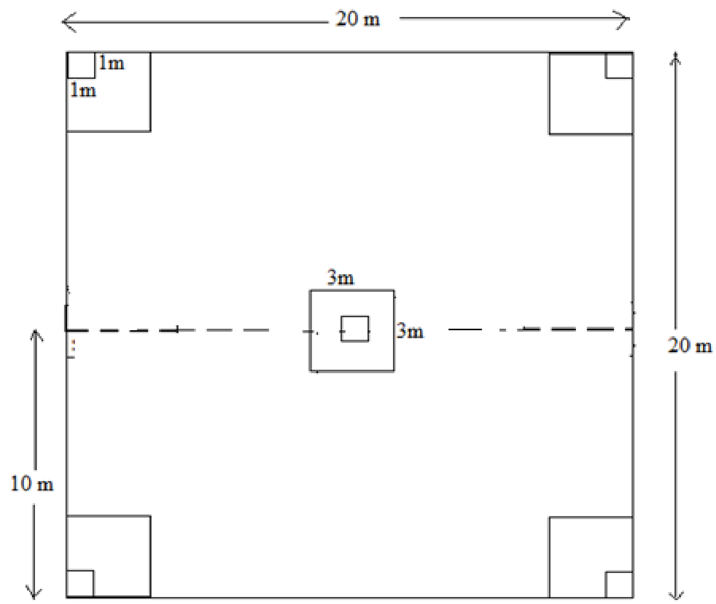

Figure 17. Sample plot design

Every plant species encountered in each sample plot was recorded. Different plant species occurring outside the plot, but inside the study area were recorded as “present”, though the species were not used in the subsequent data analysis (Tamrat Bekele, 1994). Specimens of each plant species in the study area were photographed and collected. The specimens were pressed and brought to the National Herbarium, Addis Ababa University for identification. The specimens were dried, sterilized and identified using (i) volumes of Flora of Ethiopia and Eritrea (ii) authenticated specimens and (iii) consulting experts.

4.4. Environmental data collection

The environmental variables recorded in each sample plot were altitude, aspect, slope and physical and chemical properties of soil sample. The aspect was codified according to Zerihun Woldu *et al*. (1989): N = 0; NE = 1; E = 2; SE = 3; S = 4; SW = 3.3; W = 2.5; NW = 1.3; Ridge top = 4. Geographical co-ordination, altitude and aspect were measured using Garmin GPS (Made in Taiwan), whereas slope was measured using Silva Clino Master (made in Sweden). A kilo gram of soil composite sample was collected from 0-60 cm depth, or less for shallow soils, from the four corners and the middle of a sample plot. All the soil samples were brought to Eco-physiology laboratory, Addis Ababa University. The soil samples were then air-dried, mixed well and passed through a 2 mm sieve for the analysis of its physical and chemical properties. The physical and chemical properties in the analysis of the soil sample were texture (sand, silt, and clay), pH, electrical conductivity (EC) and total dissolved salts (TDS).

4.4.1. Soil texture analysis and texture class determination

Soil texture (particle size distribution) was determined using the Boycouos hydrometric method (Bouyoucos, 1962; Van Reeuwijk, 2000) based on the following procedure: 1) removal of particles larger than 2mm diameter 2) treatment to remove cementing agents such as organic matter 3) dispersion 4) sedimentation and 5) soil texture class determination using USDA Soil Textural Triangle. The organic matter of the sample soil was removed by 30 ml water, 30 ml of 30 % hydrogen peroxide solution. A solution of dispersing agent (Calgon) was prepared by dissolving 40g dried Sodium hexametaphosphate [$(NaPO_3)_6$], and 10 g dried Sodium carbonate (Na_2CO_3) in a one liter of volumetric flask and the flask was filled with distilled water up to 1000 ml mark. The flask was plugged with stopper and shacked until it formed solution of dispersing agent.

Air-dried and ground soil composite was passed through a 2 mm sieve. 50g of the soil sample (< 2 mm) was weighed and placed in 200 ml E. flask. 100ml of the dispersing agent (Calgon solution) was placed into the flask. The flask was plugged and stirred for 3 hours on electrical shaker. The dispersed soil suspension was transferred in to a 1 L hydrometer jar and it was filled with distilled water until the volume reached 1 litter. The hydrometer jar was plugged and shacked upside down for a minute. A drop of amyl solution was dropped to shrink foam. The soil suspension in the hydrometer jar was allowed to stand and settle for 40 seconds. After 40 seconds a hydrometer and temperature reading were recorded using hydrometer and thermometer respectively. The soil solution in the hydrometer was left to settle. After 2 hours both hydrometer and temperature readings were recorded in order. A hydrometer jar filled with only 100ml of dispersing agent and 900ml of distilled water was also used as a control (pretreatment) for both hydrometer and temperature readings. The first readings of the soil suspension were used for calculating the percentage of silt and clay of the soil sample, whereas the second readings were used for calculating the percentage of clay of the soil sample.

% of Silt and clay = (H_1 + T_1 - 2) x 50g/100 ml

% of Clay = (H_2 +T_2 - 2) x 50g/100 ml

% of Sand = 100% - % of (Silt + Clay)

Where H1 = the first hydrometer reading

H_2 = the second hydrometer reading

T_1 = the first temperature reading

T_2 = the second temperature reading

Soil texture class was determined using USDA Soil Textural Triangle (1987) and FAO (2006). The determination was computed using appropriate package in the R program (Version 3.1.2) (The R core Team, 2012).

4.4.2. Soil pH, Electron Conductivity (EC), and Total Dissolved Salts (TDS) measurements

Following the method of McLean (1982), the pH of soil samples was potentiometrically measured in supernatant suspension of a 1:5 (solid: liquid) ratio. 10 gram of air-dried soil sample and 50 ml of distilled water were mixed well with glass road in a beaker. The mixture was allowed to stand for 30 minutes, but the suspension was stirred every 10 minutes during this period. A pH meter (WTW-pH-meter inoLab pH Level 2 pH meter) was calibrated with 0.01N buffer solution of pH 4 and 7. After 30 minutes, the combined electrode of the calibrated pH meter was placed into the suspension and its pH was measured and recorded. In addition, SX713Conductivity/TDS/ Salinity/Resistivity Meter was used to measure the electrical conductivity (EC in mS/cm) and total dissolved salts

(TDS) of the suspension (As described by Sahlemedhin Sertsu and Taye Bekele, 2000). TDS in ppm was determined by multiplying Corrected EC by 640 (Dahnke and Whitney, 1988).

4.5. Species Accumulation Curve

Species Accumulation Curve measures the accumulation of species when the number of sites increases. The recommended formula is Kindt's Accumulation Curve.

$$\text{Kindt's Accumulation Curve: } \hat{S}_n = \sum_{i=1}^{s} 1 - p_i \quad \text{Where } p_i = \frac{\binom{N - f_i}{n}}{\binom{N}{n}}$$

f_i is the frequency of species i and $\binom{N}{n}$ is the binomial coefficient, or the number of ways we can choose n from N individuals, and p_i gives the probabilities that species i does not occur in a sample of size n.

$\binom{N}{n} = \frac{N!}{n!(N-n)!}$ where n is number of samples taken and N is total number of individuals (samples)

It was calculated using appropriate packages in R program (Version 3.1.2).

4.6. Multivariate analysis

4.6.1. Classification (plant community determination)

Hierarchical cluster analyses were computed using appropriate packages in R program, Version 3.1.2 (The R core Team, 2012) to classify the vegetation into plant community types. Estimated percentage of aerial cover-abundance (following 1-9 scale of Braun-

Blanquet, as modified by van der Maarle, 1979) of each species was used as an input for cluster analysis. The classification was based on dissimilarity ratio for cluster analysis:

$$1 - \left(\frac{\sum (x_{k,i} * x_{k,j})}{(\sum x^2{}_{k,i} + \sum x^2{}_{k,j}) - \sum (x_{k,i} * x_{k,j})} \right)$$

Where

$x_{k,j}$ = the distance (dissimilarity) between cluster k and cluster j
$x_{k,i}$ = the distance (dissimilarity) between cluster k and cluster i

Synoptic value was calculated by multiplying mean cover-abundance with mean frequency of occurrence of a species in a community (Van der Maarel *et al*., 1987; McCune and Grace, 2002). Each cluster was designated as local plant community types and its name was given after one or two species of the cluster that have the highest synoptic value. In each plant community type the significance of synoptic value of each species were further tested with permutation based on randomizations in order to find significant indicator value of the species in the identified community types (Dufrêne and Legendre, 1997).

4.6.2. Ordination (Vegetation-environment relationship)

A canonical correspondence analysis (CCA) was employed to determine the relationship between environmental variables and community types. The analysis was computed using appropriate packages in R program, Version 3.1.2 (The R core Team, 2012).

In addition to ordination, ANOVA and Tukey's pair-wise test were calculated to determine significant difference among the community types with respect to mean of environmental variables. Furthermore, Pearson's correlations test was applied to check if there was any correlation among environmental variables. The Analysis of Variance (ANOVA) and Tukey's pair-wise test were computed using the R program (Version 3.1.2) software, while Pearson's product moment correlation coefficients were calculated using Minitab (2000) software.

Formula of Pearson's product moment correlation coefficient:

$$r = \frac{\sum \mathrm{xy} - \frac{\sum \mathrm{x} \sum \mathrm{y}}{\mathrm{n}}}{\sqrt{\left(\sum x^2 - \frac{(\sum x^2)}{\mathrm{n}}\right)\left(\sum y^2 - \frac{(\sum y^2)}{\mathrm{n}}\right)}}$$

Where r = Pearson's Correlation Coefficient

x and y are variables

n is number of observations

4.7. Species diversity analysis

Shannon and Weaver diversity index, species richness and Shannon and Weaver evenness (equitability) were computed to explain alpha-diversity in the plant community types. In addition, Sorensen's similarity coefficient was used to determine beta-diversity or the pattern of species turnover among communities along the altitude (Kent and Coker, 1992; Krebs, 1999). In both cases, percentage of cover-abundance value of all plant species of a plant community type were computed using appropriate packages in R program, Version 3.1.2 (The R core Team, 2012). The formulae for computing alpha and beta diversity are shown below.

$$Shannon\ and\ Weaver\ diversity\ index:\ H' = -\sum_{i=1}^{s} p_i\ ln\ p_i$$

Where S= total number of species

Pi = the proportion of individuals abundance of the i^{th} species

ln= log base n

$$Shannon\ equitability\ (evenness): J = \frac{H'}{H'max} = \frac{-\sum_{i=1}^{s} p_i\ ln\ p_i}{lnS}$$

Where H' is Shannon and Weaver diversity index

H'max = lnS

S = the number of species

Pi = the proportion of individuals abundance of the i^{th} species

ln = log base n

$$Beta\ diversity: \beta = \frac{b + c}{2a + b + c}$$

Where a = the number of shared species in two sites

b = the numbers of species unique to site b

c = the numbers of species unique to site c

4.8. Vegetation structure analysis

4.8.1. Density: Counting of woody individuals of plants specie per unit area (Muller-Dombois and Ellenberg, 1974) was calculated using the following formula.

$$Density = \frac{Total\ number\ of\ idividuals\ of\ woody\ species}{Sample\ size\ in\ hectare}$$

4.8.2. Relative Density: Numerical strength of a woody species in relation to the total number of woody individuals of all the species was calculated using the following formula.

$$Relative\ Density = \frac{Total\ number\ of\ idividuals\ of\ a\ woody\ species}{Total\ number\ of\ individuals\ of\ all\ woody\ species} \text{ x } 100$$

4.8.3. Frequency: The degree of dispersion of individual species in an area or the number of plots in which species recorded per a total number of plots (Goldsmith *et al*., 1986) was calculated using the following formula.

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

4.8.4. Relative Frequency: The degree of dispersion of individual species in an area in relation to the number of all the species occurred was calculated using the following formula.

$$Relative\ Frequency = \frac{Frequency\ of\ a\ species}{Total\ Frequency\ of\ all\ woody\ species}\ x\ 100$$

4.8.5. Diameter at Brest Height (DBH): It is a measurement of a stem diameter at breast height (1.3 m above ground). Circumference of a stem $\geq$ 7.85 cm at breast height was measured for woody species and the crcumfrence was converted to DBH using the following formula.

$DBH = C/\pi$ where C is Circumference of a stem at breast height

4.8.6. Basal Area: Cross section area of a stem at breast height (1.3m) was calculated using the following formula.

$Basal\ area = \pi(d/2)^2 = (DBH/2)^2 \text{ X } 3.14$ where d is diameter at breast height

4.8.7. Relative Basal Area : A percentage of a basal area of a woody species out of the total basal area of the rest woody species in sample plots was calculated using the following formula.

$$Relative\ Basal\ Area\ = \frac{Total\ basal\ area\ of\ all\ individuals\ of\ a\ species}{Basal\ area\ of\ all\ species} \text{x } 100$$

4.8.8. Importance of a woody species: Summing up of relative density, relative dominance and relative frequency of a species (Mueller-Dombois and Ellenberg 1974) was calculated using the following formula.

Importance value Index = Relative density + Relative frequency + Relative basal area

4.8.9. Vertical stratification and population structure

The vertical stratifications of trees and shrubs were determined using the IUFRO classification scheme as cited in Lamprecht (1989). Based on this scheme, the tallest tree was used as areference for determining the population vertical structure (storey). Woddy species with height greater than 2/3 of the the tallest tree represents upper storey, woody species with height between 1/3 and 2/3 of the tallest tree represented the middle storey and woody species with height less than 1/3 of the top height represented lower storey. In addition, some selected woody species were used for determining population structures and interpreting the pattern of population dynamics.

4.9. Estimating regeneration status of trees and some shrubs

Regeneration status was estimated based on the composition and density of seedling and sapling of all woody species recorded in each sample plot.

The density of seedlings and saplings were calculated based on the following formula.

$$Density\ of\ Seedling = \frac{No.of\ seedling}{hectare}$$

$$Density\ of\ \ Sapling = \frac{No.of\ sapling}{hectare}$$

Following Simon Shibru and Girma Balcha (2004), the woody species in the study area were categorized into three groups based on the number of seedlings and sapling encountered.

Group "A" = species with no seedling or1/ha

Group "B"= Species with 1 to 15 seedlings/ha

Group "C"= Species with greater than 15 seedlings/ha

Conservation priority was given to those species which were grouped under "A".

4.10. Estimating human impacts on the vegetation of the study area

Two types of disturbances recorded in each sample plot: grazing intensity and human interference. Grazing intensity was estimated following Zerihun Woldu and Backeus (1991): 0 = nil; 1 = slight; 2 = moderate and 3 = heavy. On the other hand, the degree of human disturbance in each plot was recorded using 1 – 4 scale, following Getachew Tesfaye *et al.* (2002): 1= no sign of any stump cut left; 2= one stump cut and less frequent woody collection; 3= two to three stump cut and frequent wood collection; 4= greater than three stumps cut and frequent wood collection.

4.11. Phytogeographical association

Floristic comparison was made between the Choke-Koso Ber Range and some other similar mountains in Ethiopia in order to get information on floristic similarity between the comparable vegetation of the mountains. Vegetation types and similar altitudinal rang were the primary requirements for comparison. The floristic similarities between mountains were determined using Sorensen's Coefficient Index (Kent and Coker, 1992).

$$SC = \frac{2a}{2a + a + b}$$

Where SC = Sorensen's Coefficient Index

a = number of species common to both the vegetation of the mountains.

b = number of species present in the vegetation of the first mountain but absent from the vegetation of the second mountain.

c = number of species present in the vegetation of the second mountain but absent from the vegetation of the first mountain.

CHAPTER FIVE

5. Result

5.1. Species-Accumulation Curve

Species-Accumulation Curves (Figure 18) show that adequate numbers of plots were laid down in both Afroalpine and Dry Evergreen Afromontane vegetation. The corves become asymptote when maximum number of species is captured (accumulated) as the number of plots increase.

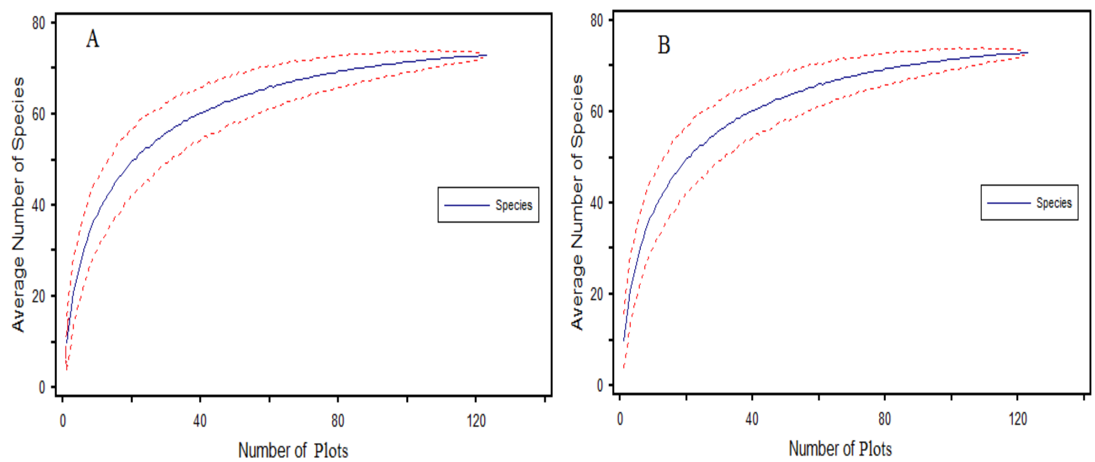

Figure 18. Species-Accumulation Curves for the vegetation of Afroalpine (A) and Dry Evergreen Afromontane (B)

5.2. Floristic composition of the study area

5.2.1. Floristic composition at a total level

A total of 243 plant species, belonging to 177 genera and 71 families were recorded from the natural vegetation of Choke - Kosso Ber Mountain Range (Appendix 1). Of these, 17 species (7%) were trees, 3 species (1.23%) were shrubs/trees, 37 species (15.23%) were shrubs, 171 species (70.37%) were herbs, 12 species (4.94%) were climbers and 3 species (1.23%) were mosses. Out of the total recorded plant species, flowering plants were represented by 228 species (93.83%), whereas non-flowering plants by 15 species (6.17%). Out of the total flowering plants, dicots were represented by 176 species (77.20%), while monocots by 52 species (22.80%).

The non flowering vascular plants included a single species, *Selaginella abyssinica* (Selaginellaceae) and eleven fern species (Pteridophytes), belonging to 10 genera and 9 families. The nonvascular were three mosses species, belonging to 3 genera and 3 families. The climber plants consisted of 8 woody (lianas) and 4 non-woody species, both were represented by 10 genera and 9 families. In addition, 12 species, belonging to 11genera and 10 families were epiphytes.

Asteraceae, Poaceae, Fabaceae and Lamiaceae were the dominant plant families in the vegetation of Choke - Kosso Ber Mountain Range (Table 3). Asteraceae was represented by 25 (14%) genera and 39 (16%) species, Poaceae by14 (7.87%) genera and 28 (11.5%) species, Fabaceae by 8 (4.49%) genera and Lamiaceae by 13 (5.33%) species. Half of the total families (36 families) were represented by a single genus and species, whereas the remaining 36 families were represented by two or more than two genera and species.

Table 3. Ten plant families with highest number of genera and species in the vegetation Choke-Kosso Ber Mountain range

S. No.	Family	No. of Genera	% of Genera	No. of Spp.	% of Spp.
1	Asteraceae	25	14	39	16.0
2	Poaceae	14	7.87	28	11.5
3	Fabaceae	8	4.49	13	5.33
4	Lamiaceae	6	3.37	11	4.51
5	Apiaceae	7	3.93	8	3.28
6	Caryophyllaceae	7	3.93	8	3.28
7	Brassicaceae	4	2.25	6	2.46
8	Crassulaceae	4	2.25	6	2.46
9	Cyperaceae	5	2.81	6	2.46
10	Rosaceae	5	2.81	6	2.46

5.2.2. Floristic comparison between Afroalpine and Dry Evergreen Afromontane vegetation

One hundred forty one plant species belonging to 103 genera and 40 families were recorded in the Afroalpine vegetation. The most dominant species in this vegetation were Asteraceae (represented by 32 species and 21 genera), Poaceae, (represented by 19 species and 10 genera) and Lamiaceae (represented by 9 species and 5 genera). On the other hand, 147 plant species belonging to 118 genera and 62 families were recorded in the Dry Evergreen Afromontane vegetation. The most dominant species in this vegetation were Asteraceae (represented by 19 species and 15 genera), Poaceae (represented by 12 species and 10 genera) and Fabaceae (represented by 10 species and 7 genera).

Table 4. Growth habits in Afroalpine and Dry Evergreen Afromontane vegetation (* represents unspecified growth habit)

Habit	Afroalpine		Dry Evergreen Afromontane	
	Spp. no.	Percent	Spp. no.	Percent
Climbers	2	1.42	8	5.44
Herbs	116	82.27	92	62.59
Shrubs	20	14.18	25	17.01
Shrub/tree	0	0	3	2.04
Tree	1	0.71	17	11.56
*Moss Spp.	2	1.42	2	1.36
Total	**141**	**100**	**147**	**100**

There were 42 plant species, belonging to 40 genera and 23 families common to Afroalpine and Dry Evergreen Afromontane vegetation. The common species were represented by 1 tree species, 6 shrub species, 31 herb species and 2 climber species and 1 moss species. The Sorenson's floristic similarity index between the two vegetations was 29%.

5.2.3. Plant species recorded in Choke-Koso Ber Mountain Range but not reported in Gojjam Floristic Region of the Flora of Ethiopia and Eritrea

The Choke-Koso Ber Mountain Range is located in Gojjam (GJ) Floristic Region of the Flora of Ethiopia and Eritrea. Out of the total species recorded in the mountain range, 47 species, belonging to 44 genera and 30 families are not reported in the Gojjam Floristic Region of the Flora (Appendix 3). Of these, 36 species were herbs, 8 species were shrubs, 2 species were climbers and 1 species was a tree.

5.2.4. Endemic plants of Ethiopia recorded in vegetation of Choke-Koso Ber Mountain Range

Out of 243 plant species recorded in the vegetation of Choke-Koso Ber Mountain range, 33 species (13.58%), belonging to 27 general and 15 families were endemic plant of Ethiopia (Appendix 2).

Table 5. Taxa of endemic plants of Ethiopia in the vegetation of Choke -Kosso Ber Mountain range

S.No.	Family	No. of Genera	% genera	No. Spp.	% of species
1	Asteraceae	8	28.57	9	27.27
2	Crassulaceae	2	7.14	3	9.09
3	Fabaceae	2	7.14	3	9.09
4	Poaceae	2	7.14	3	9.09
5	Asphodelaceae	1	3.57	2	6.06
6	Caryophyllaceae	2	7.14	2	6.06
7	Lamiaceae	2	7.14	2	6.06
8	Lobeliaceae	2	7.14	2	6.06
9	Acanthaceae	1	3.57	1	3.03
10	Apiaceae	1	3.57	1	3.03
11	Commelinaceae	1	3.57	1	3.03
12	Ranunculaceae	1	3.57	1	3.03
13	Saxifragaceae	1	3.57	1	3.03
14	Scrophulariaceae	1	3.57	1	3.03
15	Urticaceae	1	3.57	1	3.03

Out of 33 endemics, 28 species (85%) were herbs, 3 species (9%) were shrubs, 1 species (3%) was a tree and 1species (3%) was a climber. The family in which highest number of the endemic species recorded was Asteraceae (9 endemic species), followed by Crassulaceae, Fabaceae and Poaceae (each with 2 endemic species) (Table 5).

The number of endemic plant species restricted to the Afroalpine vegetation was 14 (42.4%), while the number of endemic plant species restricted to Dry Evergreen Afromontane vegetation was 12 (36.4%). The remaining 7 species (21.2%) were common endemic plant species to both Afroalpine and Dry Evergreen Afromontane vegetation.

Endemic plant species restricted to the Afroalpine vegetation were *Anarrhinus forkaohlii* subsp. *abyssinicum* (Scrophulariaceae), *Cineraria sebaldii* (Asteraceae), *Cyanotis polyrrhiza* (Commelinaceae), *Euryops pinifolius* (Asteraceae), *Festuca macrophylla* (Poaceae), *Kalanchoe petitiana* var. *neumannii* (Crassulaceae), *Lobelia rhyncopetalum* (Lobeliaceae), *Poa chokensis* (Poaceae), *Poa hedbergii* (Poaceae), *Polycarpon tetraphyllum* (Caryophylaceae), *Sagina abyssinica* (Caryophyllaceae), *Sedum mooneyi* (Crassulaceae), *Thymus schimperi* (Lamiaceae) and *Urtica simensis* (Urticaceae).

Endemic plant species restricted to the Dry Evergreen Afromontane vegetation were *Bidens pachyloma* (Asteraceae), *Erythrina brucei* (Fabaceae), *Justiacea diclipteroides* (Acanthaceae), *Kniphofia insignis* (Asphodelaceae), *Lobelia erlangeriana* (Lobeliaceae), *Mikaniopsis clematoides* (Asteraceae), *Peucedanum petitianum* (Apiaceae), *Satureja paradoxa* (Lamiaceae), *Saxifraga hederifolia* (Saxifragaceae), *Solanecio gigas* (Asteraceae), *Thalictrum schipmerianum* (Ranunculaceae) and *Trifolium bilineatum* (Fabaceae).

The common endemic plant species belonging to both Afroalpine and Dry Evergreen Afromontane vegetation were *Bidens macroptera (*Asteraceae), *Bothriocline schimperi* (Asteraceae), *Echinops longisetus* (Asteraceae), *Kalanchoe schimperiana* (Crassulaceae), *Kniphofia foliosa* (Asphodelaceae), *Launaea rueppellii* (Asteraceae), *Trifolium decorum* (Fabaceae).

5.3. Cluster analysis

Three clusters, belonging to Afroalpine vegetation (Figure 19) and five clusters, belonging to Dry Evergreen Afromontane vegetation (Figure 31) were identified in the outputs of Agglomerative Hierarchical Classification. Each cluster was designated as local plant community type and its name was given after one or two species of the cluster that have the highest synoptic value. Priority was given to a tree and a shrub.

5.3.1. Clusters analysis for Afroalpaine vegetation

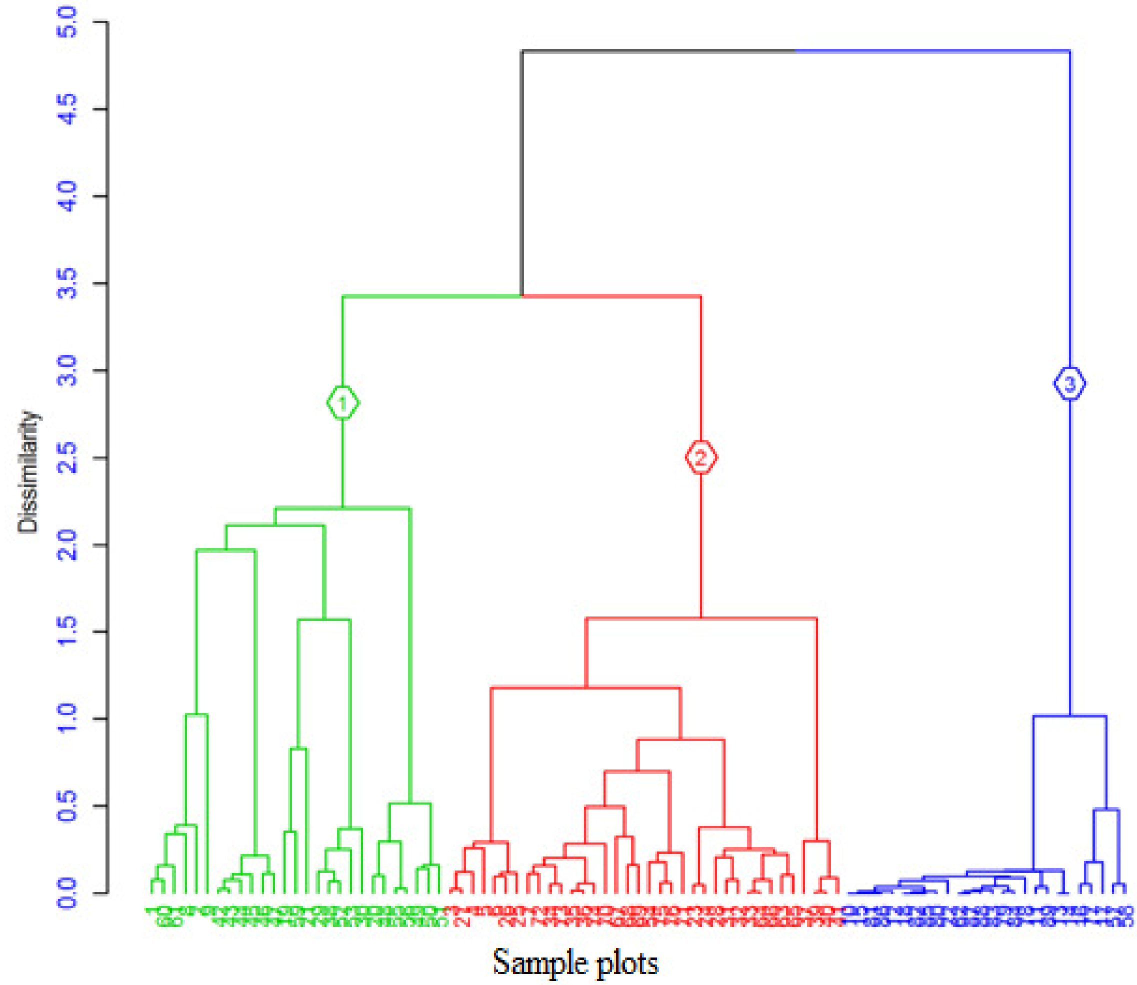

Figure 19. Dendrogram showing clusters of sample plots of Afroalpine vegetation

Three clusters of the sample plots are distinctly recognized. Green, red and blue colors represent cluster one, two and three, respectively (Figure 19).

Table 6 shows synoptic cover-abundance value for species of Afroalpine vegetation. The name of each community type was given after one or two bold species with highest synoptic value that occurred in each cluster.

Table 6. Synoptic cover- abundance value for species of Afroalpine vegetation

Species	**Cluster 1**	**Cluster 2**	**Cluster 3**
Koeleria pyramidata	2.33	0	0
Trifolium Cryptopodium	2.11	0	0
Deschampsia caespitosa	1.82	0.92	0
Kniphofia foliosa	1.82	0.11	0
Festuca macrophylla	1	0.53	0
Euryops pinifolius	0.52	7.89	0
Alchemilla abyssinica	3.37	3.42	0.58
Trifolium acaule	1.59	3.14	0.42
Lobelia rhyncopetalum	0.48	2.25	0.19
Helichrysum citrispinum	0.19	1.39	0
Poa annua	0.48	1.08	0.58
Erica arborea	0.11	0.08	8.62
Hypericum revolutum	0.04	0	1.54
Cotula cryptocephala	0.85	0.81	0.15
Echinops longisetus	0	0	0.96
Galium aparinoides	0	0	0.08
Hagenia abyssinica	0	0	0.35
Rosa abyssinica	0	0	0.08
Cerastium octandrum	0.78	0.06	0
Cotula abyssinica	0.74	0.89	0
Alchemilla microbetula	0.67	0.25	0
Dianthoseris schimperi	0.41	0.47	0
Deschampsia caespitosa	0	0.31	0
Satureja pseudosimensis	0.11	0.17	0
Crepis rueppellii	0.04	0.06	0
Sagina abyssinica	0	0.06	0
Haplocarpha rueppellii	0.26	0.06	0
Haplocarpha schimperi	0.63	0	0
Oxalis procumbens	0.59	0	0

Species	Cluster 1	Cluster 2	Cluster 3
Andropagon distachyos	0.56	0	0
Merendera schimperiana	0.52	0	0
Swertia abyssinica	0.52	0	0
Crassula schimperi	0.37	0	0
Anthemis tigreensis	0.19	0	0
Bidens macroptera	0.19	0	0
Satureja biflora	0.19	0	0
Geranium arabicum	0.15	0	0
Hydrocotyle sibthorpioides	0.15	0	0
Kalanchoe schimperiana	0.15	0	0
Pennisetum humile	0.15	0	0
Phytolacca dodecandra	0.15	0	0
Salvia nilotica	0.15	0	0
Subularia monticola	0.15	0	0
Abildgaardia boeckeleriana	0.07	0	0
Epilobium stereophyllum	0.07	0	0
Festuca abyssinica	0.07	0	0
Gnaphalium rubriflorum	0.07	0	0
Poa leptoclada	0.07	0	0
Rumex abyssinicus	0.07	0	0

Indicator value for species of Afroalpine vegetation is shown in Table 7. The p-value is based on the proportion of randomized trials (Runs) with indicator value. Species with significant maximum value ($p \leq 0.05$) are indicators. The indicator species of each community type are in bold type.

Table 7. Indicator value for species of Afroalpine vegetation

Species	Cluster	Indicator value	p-value
Carduus schimperi	**1**	**0.333**	**0.001**
Cerastium octandrum	**1**	**0.449**	**0.001**
Haplocarpha schimperi	**1**	**0.259**	**0.001**
Koeleria pyramidata	**1**	**0.259**	**0.001**
Merendera schimperiana	**1**	**0.222**	**0.001**
Trifolium Cryptopodium	**1**	**0.593**	**0.001**
Kniphofia foliosa	**1**	**0.244**	**0.003**
Andropagon distachyos	**1**	**0.185**	**0.008**
Swertia abyssinica	**1**	**0.185**	**0.008**
Oxalis procumbens	**1**	**0.148**	**0.017**
Satureja biflora	1	0.111	0.054
Alchemilla microbetula	1	0.108	0.076
Deschampsia caespitosa	1	0.148	0.095
Rumex abyssinicus	1	0.074	0.155
Andropagon distachyos	1	0.074	0.169
Geranium arabicum	1	0.074	0.172
Bidens macroptera	1	0.074	0.173
Anthemis tigreensis	1	0.074	0.177
Kalanchoe schimperiana	1	0.074	0.178
Salvia nilotica	1	0.074	0.184
Epilobium stereophyllum	1	0.037	0.575
Festuca abyssinica	1	0.037	0.599
Gnaphalium rubriflorum	1	0.037	0.6
Dianthoseris schimperi	1	0.037	0.602
Euryops pinifolius	**2**	**0.938**	**0.001**
Lobelia rhyncopetalum	**2**	**0.727**	**0.001**
Trifolium acaule	**2**	**0.524**	**0.001**
Alchemilla abyssinica	**2**	**0.4**	**0.004**
Helichrysum citrispinum	**2**	**0.27**	**0.004**
Dianthoseris schimperi	2	0.164	0.081
Deschampsia caespitosa	2	0.083	0.112
Cotula abyssinica	2	0.152	0.14
Poa annua	2	0.169	0.148
Cotula cryptocephala	2	0.185	0.193
Satureja pseudosimensis	2	0.05	0.429

Species	Cluster	Indicator value	p-value
Festuca macrophylla	2	0.086	0.431
Crepis rueppellii	2	0.017	0.884
Sagina abyssinica	2	0.028	1
Echinops longisetus	**3**	**0.269**	**0.001**
Erica arborea	**3**	**0.978**	**0.001**
Hypericum revolutum	**3**	**0.864**	**0.001**
Hagenia abyssinica	**3**	**0.308**	**0.002**
Rosa abyssyinica	3	0.038	0.282
Galium aparinoides	3	0.038	0.321

Table 8. Plots number, plot codes and altitudinal range of each community type of Afroalpine vegetation

Comm type	Altitudinal range (m)	No. of plots	Plot cods in the communities
1	3430 – 4080	27	1, 2, 8, 18,19, 20, 21, 23,24,25,26,27, 38, 49, 50, 51, 52, 53, 55, 56, 60, 61,62,86,87,88,89
2	3515 – 4000	36	9,10,11,12,13,14,15,16,17,22, 34,35,36, 37,39,40,41, 42, 43,44,45,46,47,48,57,58,59, 77,78, 79,80,81,82, 83, 84, 85
3	3450 – 3814	26	3,4,5,6,7,28,29,30,31,32,33,54, 63,64,65,66, 67,68, 69, 70, 71, 72, 73, 74, 75,76,

5.3.1.1. Description of community types

Community 1: *Koeleria pyramidata - Trifolium cryptopodium* type

This herbaceous community type is situatedat at altitude between 3430 and 4080 m. Species such as *Carduus schimperi*, *Cerastium octandrum, Swertia abyssinica*, *Haplocarpha schimperi*, *Andropagon distachyos*, *Merendera schimperiana*, *Kniphofia* *foliosa* and *Swertia abyssinica* were indicator species. *Clematis simensis* was the only climber that had been recorded in the community type. This community type consisted of heterogeneous environments.

Koeleria pyramidata (Figure 20) was a dominant grass species in the community type. Others species such as *Festuca macrophylla*, *Andropagon distachyos*, *Trifolium Cryptopodium*, *Cerastium octandrum*, *Cotula abyssinica, Poa annua*, *Rumex abyssinicus*, *Sedum mooneyi*, *Trifolium acaule*, *Alchemilla abyssinica*, *Anthemis tigreensis*, *Geranium arabicum*, *Carduus schimperi*, *Salvia nilotica*, *Satureja pseudosimensis*, *Vulpia bromoides*, *Gnaphalium rubriflorum*, *Kniphofia foliosa*, *Oxalis procumbens* and *Alchemilla microbetula, Swertia abyssinica* were found in these grasslands. Though, most parts of this community type were overgrazed, *Festuca macrophylla* profusely (Figure 21) grew on the plateau of Arat-Mekerakir.

Figure 20. *Koeleria pyramidata* dominated site

Figure 21. *Festuca macrophylla* dominated site

Figure 22. *Kniphofia foliosa* dominated site

Figure 23. *Deschampsia caespitosa* dominated site

Common species in the wetlands were *Haplocarpha rueppellii* and *Subularia monticola* (Figure 24 - 26). Other species such as *Deschampsia caespitosa*, *Abildgaardia boeckeleriana*, *Cotula cryptocephala*, *Epilobium stereophyllum, Hydrocotyle sibthorpioides* and *Cotula cryptocephala* were also recorded in these wetlands.

Figure 24. *Haplocarpha rueppellii* dominated site

Figure 25. *Subularia monticola* (a herb species with white flower)

Figure 26. *Hydrocotyle sibthorpioides* (a herb species suspended in fresh water)

Community 2: *Euryops pinifolius - Alchemilla abyssinica* type

This community type was distributed at altitudes between 3515 and 4000 m. It covered the largest area of Afroalpine vegetation with large number of plant species. *Lobelia rhyncopetalum, Euryops pinifolius, Trifolium acaule* and *Helichrysum citrispinum* were indicator species. *Euryops pinifolius* was the most dominant shrub since it is not palatable (Figure 27 - 29).

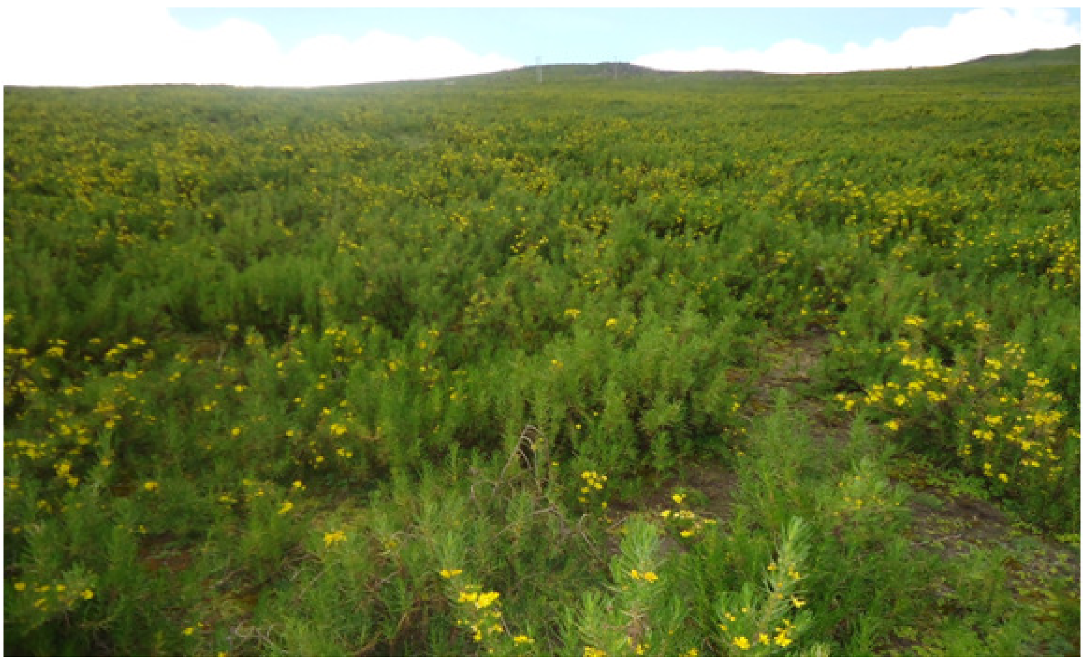

Figure 27. *Euryops pinifolius*: a dominant shrub in *Euryops pinifolius* - *Alchemilla abyssinica* community type

In the higher altitude where low temperature (~8^0C) occurred, *Alchemilla abyssinica* was a dominant herb, including other herbaceous species such as *Dianthoseris schimperi*, *Merendera schimperiana*, *Cerastium octandrum*, *Cotula abyssinica*, *Cotula cryptocephala*, *Haplocarpha schimperi* and *Trifolium acaule* (Figure 28). *Helichrysum citrispinum* was frequently distributed in rocky and degraded sloppy lands (Figure 29.1).

In addition, herbs such as *Deschampsia caespitosa*, *Poa annua*, *Swertia abyssinica*, *Umbilicus botryoides* and *Trifolium cryptopodium* were found in this community type.

Figure 28 *Alchemilla abyssinica, a dominant* sp. in the *Euryops pinifolius - Alchemilla abyssinica* community type (The species in the figure include *Alchemilla abyssinica*, *Trifolium cryptopodum*, *Trifolium acaule*, *Merendera schimperiana* and *Launaea rueppellii*)

Figure 29. *Euryops pinifolius* - *Alchemilla abyssinica* community type (a site dominated with *Lobelia rhyncopetalum* and *Helichrysum citrispinum*)

Figure 29.1. *Helichrysum citrispinum* frequently grew in stony and degraded land

Community 3: *Erica arborea* type

This community type was distributed at altitude between 3450 and 3814 m altitude. In addition to *Erica arborea,* other species such as*, Hypericum revolutum, Hagenia abyssinica* and *Echinops longisetus* were indicator species of the community type. *Rosa abyssinica* was recorded on 'Arat-Mekerakir' plateau only in less frequent. Many *Echinops longisetus* were profusely grown where Erica shrubs were removed by cut and it was distinguished as white vegetation as it was seen from a distance area.

The representative herbs in this Community type included *Alchemilla abyssinica*, *Cotula abyssinica*, *Cotula cryptocephala*, *Lobelia rhyncopetalum*, *Hypolepis goetzei*, *Poa annua*, *Trifolium acaule*, *Satureja pseudosimensis*, *Euryops pinifolius*, *Thymus schimperi* and *Silene burchellii*. Most frequently a mass of moss species grew on the ground under the *Erica* shrub.

Figure 30. *Erica arborea* community type

Some *Lobelia rhyncopetalum* grew sparsely between Erica shrubs. *Rubus steudneri* was the only woody climber recorded on the flat top of Arat Mekerakir. Most parts of this community type were well protected (Figure 30).

5.3.2. Plant community types in the Dry Evergreen Afromontane vegetation

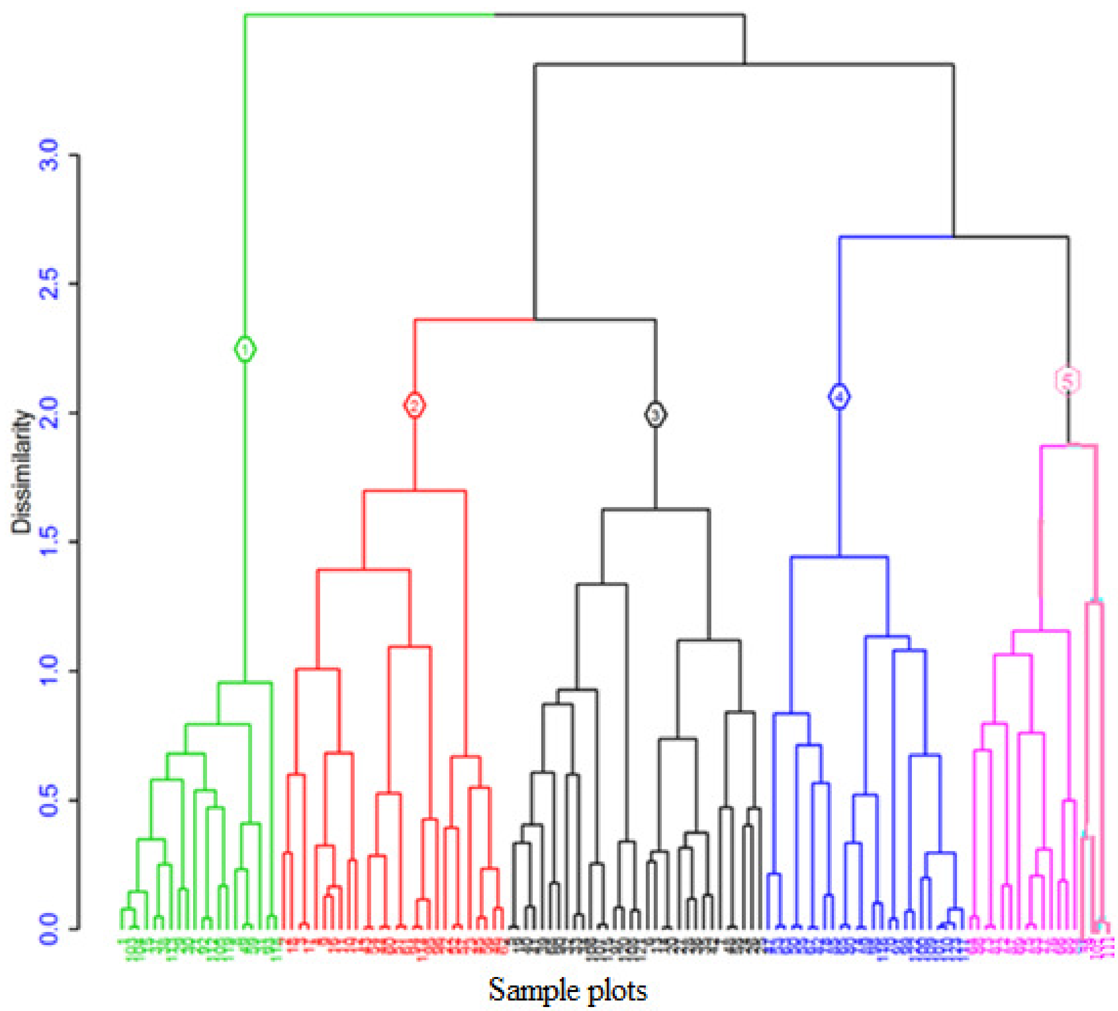

Figure 31. Dendrogram showing cluster of sample plots of Dry Evergreen Afromontane vegetation

The green, red, black blue and pink colors represent cluster one, two, three, four and five, respectively (Figure 31).

Synoptic cover-abundance value for species of Dry Evergreen Afromontane vegetation is shown in Table 9. The name of each community type was given after one or two bold species with highest synoptic value that occurred in each cluster.

Table 9. Synoptic cover-abundance value for species of Dry Evergreen Afromontane vegetation

Species	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Acacia abyssinica	7.75	3.75	0.19	0	0.44
Bersama abyssinica	3.5	2.57	1.5	1.32	1.83
Brucea antidysenterica	3.15	1.36	1.56	0.84	0.83
Vernonia myriantha	2.35	2.25	0.66	0.76	1.33
Dombeya torrida	0.1	3.71	0.34	1.44	0
Pittosporum virdiflorum	0.15	3.57	0.41	2	1.61
Nuxia congesta	0.1	1.96	1.06	0.48	0.83
Clutia lanceolata	0.6	1.54	0.47	0	0.67
Gnidia glauca	0.7	1.5	0.56	0	0
Buddleja polystachya	0	1.04	1.12	1.08	0.44
Maytenus arbutifolia	1.15	3.54	5.62	3.68	0.83
Maesa lanceolata	0.75	4.79	5.22	2.04	1.5
Rosa abyssinica	0	0.25	1.47	0	0
Schefflera abyssinica	0	0	0	6.96	0
Myrsine melanophloeos	0	0.18	0.56	2.08	0
Prunus africana	0	0	0.75	3.32	4.39
Alophyllus abyssincus	0.4	0	0.38	0	3.83
Canthium oligocarpum	0.15	0.11	0	0.72	1.22
Galiniera coffeoides	0	0	0	0.52	1.22
Dovyalis abyssinica	0.25	0	0.06	0	1.11
Albizia schimperiana	0	0	0.12	0.44	0
Euphorbia amliphylla	0	0	0.19	0.24	0
Cynodon dactylon	0	0	0	0	0.94
Pamiletum thunbergii	0	0	0	0	0.89
Trifolium steudneri	0	0	0	0	0.78
Erythrina brucei	0	0	0.12	0	0.11

Species	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Asparagus africanus	0	0.21	0.06	0	0.56
Vernonia auriculifera	0.85	0	0.09	0	0
Hypericum revolutum	0	0.5	0.44	0	0
Erica arborea	0	0	0.47	0	0
Rumex nervosus	0	0	0.19	0	0
Solanum indicum	0	0	0.06	0	0
Geranium aculeolatum	0	0	0	0	0.72
Clausena anisata	0	0	0	0	0.67
Bidens pachyloma	0	0	0	0	0.56
Ekebergia capensis	0	0	0	0	0.5
Poa annua	0	0	0	0	0.44
Cotula abyssinica	0	0	0	0	0.39
Haplocarpha schimperi	0	0	0	0	0.33
Plantago lanceolata	0	0	0	0	0.33
Vulpia bromoides	0	0	0	0	0.33

Indicator value for the species of each cluster is shown in Table 10. The p-value is based on the proportion of randomized trials (Runs) with indicator value. Species with significant maximum value ($p \leq 0.05$) are indicators. The indicator species of each community type are in bold type.

Table 10. Indicator values for species of Dry Evergreen Afromontane Vegetation

Species	Cluster	Indicator value	p-value
Acacia abyssinica	**1**	**0.604**	**0.001**
Brucea antidysenterica	**1**	**0.261**	**0.002**
Bersama abyssinica	**1**	**0.284**	**0.003**
Vernonia myriantha	**1**	**0.246**	**0.003**
Dombeya torrida	1	0.114	0.299
Gnidia glauca	**2**	**0.345**	**0.001**
Vernonia auriculifera	2	0.072	0.115
Solanum indicum	2	0.036	0.722
Buddleja polystachya	**3**	**0.323**	**0.001**
Maesa lanceolata	**3**	**0.229**	**0.001**

Species	Cluster	Indicator value	p-value
Maytenus arbutifolia arbutifolia	**3**	**0.323**	**0.001**
Hypericum revolutum	**3**	**0.191**	**0.002**
Erica arborea	**3**	**0.156**	**0.004**
Rubus steudneri	**3**	**0.193**	**0.008**
Clutia lanceolata	3	0.113	0.171
Nuxia congesta	3	0.108	0.316
Rumex nepalensis	3	0.04	0.422
Pittosporum virdiflorum	3	0.098	0.647
Albizia schimperiana	**4**	**0.446**	**0.001**
Myrsine melanophloeos	**4**	**0.929**	**0.001**
Schefflera abyssinica	4	0.06	0.193
Euphorbia amliphylla	4	0.045	0.332
Discopodium penninervium	4	0.035	0.508
Allophylus abyssincus	**5**	**0.663**	**0.001**
Canthium oligocarpum	**5**	**0.247**	**0.001**
Clausena anisata	**5**	**0.222**	**0.001**
Galiniera coffeoides	**5**	**0.312**	**0.001**
Prunus africana	**5**	**0.372**	**0.001**
Ekebergia capensis	**5**	**0.167**	**0.002**
Geranium aculeolatum	**5**	**0.167**	**0.003**
Trifolium steudneri	**5**	**0.167**	**0.003**
Dovyalis abyssinica	**5**	**0.172**	**0.005**
Bidens pachyloma	**5**	**0.111**	**0.018**
Pamiletum thunbergii	**5**	**0.111**	**0.02**
Vulpia bromoides	**5**	**0.111**	**0.02**
Cotula abyssinica	**5**	**0.111**	**0.021**
Haplocarpha schimperi	**5**	**0.111**	**0.021**
Plantago lanceolata	**5**	**0.111**	**0.026**
Cynodon dactylon	**5**	**0.111**	**0.027**
Asparagus africanus	5	0.074	0.152
Erythrina brucei	5	0.026	0.6
Poa annua	5	0.111	0.624

Table 11. Number of plots, plot codes and altitudinal ranges in the community types of Dry Evergreen Afromontane vegetation

Comm. type	Altitudinal range	No. of plots	Plot codes in the community
1	2530 -2650	20	1,8,15,21,29,30,31,37,38,49,59,92,93,103,104,105,112,113,118,119
2	2545 -2695	28	2,3,4,9,10,11,12,16,17,18,22,23,43,44,45,46,51,52,54,56,57,60,61,62,94,95,96,114
3	2505 - 2735	32	5,6,7,13,14,19,20,24,25,26,27,28,32,33,34,35,36,39,40,41,42,48,58,68,90,97,106,107,108,115,120,121
4	2520 - 2725	25	47,50,53,55,63,65,67,70,74,78,80,82,85,89,91,98,99,100,101,109,110,116,117,122,123
5	2480 - 2685	18	64,66,69, 71,72,73,75,76,77, 79,81,83,84,86,87, 88, 102,111

The community types identified in the Dry Evergreen Afromontane region are described as the following.

Community 1: *Acacia abyssinica - Bersama abyssinica* type

This community type was found within altitudinal range of 2530 - 2650 m. *Acacia abyissinica*, *Bersama abyssinica*, *Brucea antidysenterica* and *Vernonia myriantha* were indicator species. It was located in the lower altitudinal rang of the mountains and it was physiognomically distinctive by flat crown of *Acacia abyissinica* trees. In most plots of this community type, the flat crown of the matured trees have almost overlapped or connected end to end (Figure 32).

Figure 32. *Acacia abyssinica* - *Bersama abyssinica* community type

Other tree species such as, *Allophylus abyssincus*, *Maesa lanceolata*, *Pittosporum virdiflorum*, *Maytenus arbutifolia* and *Nuxia congesta* were widely distributed in this community type. *Dovyalis abyssinica* and few *Bersama abyssinica* were found in the form of smallest trees in the vegetation of Guble and Kurub mountains.

The most dominant shrubs in the open space of this community type were *Bersama abyssinica* and *Brucea antidysenterica.* Other*s* shrubs like *Vernonia auriculifera*, *Vernonia myriantha*, *Clutia lanceolata*, *Glycine wightii*, *Hypericum quartinianum, Bothriocline schimperi* were found in the lower storey.

The most dominant herbs were *Girardinia bullos* and *Hypoestes forskaolii*, especially in the vegetation of Darken Mountain. *Poa annua*, *Cynodon dactylon*, *Plantago palmate*, *Alchemilla abyssinica*, *Cerastium octandrum* and *Satureja paradoxa* also grew in open spaces. *Asplenium aethopicum* and *Blechnum attenuatum* were common epiphytic ferns on the trees, while *Selaginella abyssinica* was common species in the shady ground. *Embelia schimperi* was climber species in the community type.

Community 2: *Dombeya torrida - Pittosporum virdiflorum* type

This community type was found at altitudes between 2545 and 2695 m. *Dombeya torrid, Pittosporum virdiflorum* and *Gnidia glauca* were indicator tree species. Others species such as *Maesa lanceolata, Maytenus arbutifolia, Nuxia congesta,* and *Buddleja polystachya* also found in tree level. Shrubs species occurring in this type included *Clutia lanceolata*, *Gnidia glauca, Rosa abyssinica*, *Canthium oligocarpum, Hypericum revolutum* and *Erica arborea*.

Community 3: *Maytenus arbutifolia- Maesa lanceolata* type

This community type was situated at altitudes between 2505 and 2735 m. The community was named after maximum synoptic value of *Maesa lanceolata, Maytenus arbutifolia* (Figure 33). In addition to these two trees species*, Erica arborea*, *Buddlja polystachya* and *Hypericum revolutum* were indicator species. Trees species such as *Acacia abyssinica, Allophylus abyssincus, Dombeya torrida, Euphorbia amliphylla*, *Myrsine melanophloeos, Nuxia congesta* and *Pittosporum virdiflorum* were sparsely distributed in this community.

Species such as *Brucea antidysenterica*, *Bersama abyssinica*, *Canthium oligocarpum*, *Clutia lanceolata, Galiniera coffeoides*, *Gnidia glauca*, *Maytenus gracilipes*, *Rosa abyssinica*, *Rumex nervosus*, *Satureja punctata*, *Solanecio gigas*, *Solanum indicum* and *Vernonia myriantha* were representative shrubs of the community type.

Figure 33. *Maytenus arbutifolia* var. *arbutifolia*, a dominant species in the *Maytenus arbutifolia*- *Maesa lanceolata* type

Pleopeltis macrocarpa, *Asplenium aethopicum*, *Asplenium theciferum*, *Blechnum attenuatum* and *Pleopeltis macrocarpa* were common epiphytic plants. They were most often found on the stem of old *Maytanus arbutifolia* trees. The common climbers in this community included *Urera hypselodendron*, *Embelia schimperi*, *Phragmanthera regulari*, *Rubus steudneri* and *Mikaniopsis clematoides.*

The representative herb species were *Achyrospermum schimperi*, *Alchemilla abyssinica*, *Cotula abyssinica*, *Hypoestes forskaolii*, *Hypoestes triflora*, *Poa annua*, *Satureja paradoxa*, *Selaginella abyssinica*, *Trifolium steudneri*, *Scadox multiflorus* and *Geranium arabicum.*

Community 4: *Schefflera abyssinica - Myrsine melanophloeos* type

This community type was situated at altitudes between 2520 and 2725 m. The community was represented by the maximum synoptic value of *Schefflera abyssinica and Myrsine melanophloeos*. The indicator species in this community type were *Albizia schimperiana* and *Myrsine melanophloeos*. The mature *Schefflera abyssinica* was huge tree with massive branches in the forest that could be identified from a distance (Figure 34). Others specie such as *Buddleja polystachya*, *Albizia schimperiana*, *Dombeya torrida*, *Maesa lanceolata*, *Maytenus arbutifolia*, *Nuxia congesta*, *Pittosporum virdiflorum*, *Prunus africana* and *Teclea nobilis* were recorded in tree level.

Figure 34. *Schefflera abyssinica*, a dominant species in *Schefflera abyssinica* - *Myrsine melanophloeos* type

The representative shrubs were *Brucea antidysenterica*, *Bersama abyssinica*, *Canthium oligocarpum*, *Clausena anisata*, *Clutia lanceolata*, *Discopodium penninervium*, *Galiniera coffeoides*, *Solanecio gigas*, *Vernonia auriculifera* and *Vernonia myriantha.*

The representative herbs were *Achyranthes aspera*, *Alchemilla abyssinica*, *Cerastium octandrum*, *Girardinia bullosa*, *Hypoestes forskaolii*, *Poa annua*, *Trifolium steudneri* and *Vulpia bromoides*.

Canarina abyssinica, *Pleopeltis macrocarpa*, *Asplenium aethopicum* and *Asplenium theciferum* were common epiphytes on *Schefflera abyssinica* tree, whereas *Embelia schimperi*, *Rubus steudneri* and *Urera hypselodendron* were climber species in the community type.

Community 5: *Prunus africana - Allophylus abyssincus* type

This community type was found between 2480 and 2685m altitudes (Figure 35). Trees such as *Allophylus abyssincus*, *Prunus africana* and *Ekebergia capensis*; shrubs such as *Canthium oligocarpum*, *Clausena anisata* and *Galiniera coffeoides*; herbs such as *Bidens pachyloma*, *Geranium arabicum*, *Vulpia bromoides* and *Pennisetum thunbergii* were indicator species in this community type. Trees species included in the type were *Pittosporum virdiflorum*, *Maesa lanceolata*, *Maytenus arbutifolia*, *Buddleja polystachya*, *Ekebergia capensis*, *Nuxia congesta*, and *Acacia abyssinica.* Shrub species recorded in this type were *Bersama, abyssinica*, *Brucea antidysenterica*, *Bothriocline schimperi*, *Canthium oligocarpum, Clausena anisata*, *Clutia lanceolata, Galiniera coffeoides*, *Solanecio giga* and *Vernonia myriantha.*

Figure 35. *Prunus africana - Allophylus abyssincus* community type

Pennisetum thunbergii, *Andropogon abyssinicus*, *Cynodon dactylon* and *Poa annua* were dominant grasses species. Other herbs included in this community type were *Bidens pachyloma*, *Hypoestes triflora*, *Plantago lanceolata*, *Cotula abyssinica, Alchemilla abyssinica*, *Achyranthes aspera*, *Trifolium steudneri*, *Vulpia bromoides*, *Achyrospermum schimperi*, *Cerastium octandrum*, *Geranium arabicum*, *Hypoestes forskaolii*, *Satureja paradoxa*, *Cyanoglossum amplifolium* and *Thalictrum schimperianum.* The climbers in the community were *Asparagus africanus*, *Rubus steudneri*, *Urera hypselodendron* and *Mikaniopsis clematoides*.

5.4. Diversity

5.4.1. α (Alpha)-diversity in Afroalpine vegetation

Shannon and Weaver indices in Table 12 show that the highest plant diversity, species richness and evenness occurred in community type 1, whereas the least plant diversity and richness occurred in community type 3, though its evenness was greater than community type 2.

Table 12. Shannon and Weaver diversity indices in the communities of Afroalpine vegetation

Comm.	Richness	H'	Shannon and Weaver Evenness
1	91	3.875	0.859
2	42	2.789	0.746
3	30	2.658	0.781

5.4.2. β (Beta)-diversity in Afroalpine vegetation

Community types 1 and 3 showed the least plant species similarity (the highest β-diversity), whereas community types 1 and 2 showed the highest plant species similarity (the least β-diversity). All community types exhibited beta diversity indices greater than 0.30 in this Afroalpine vegetation (Table 13).

Table 13. β-diversity in the communities of Afroalpine vegetation
(Pair-wise comparison between 3 community types)

Comm.	1	2	3
1			
2	0.455		
3	0.669	0.619	0

5.4.3. α (Alpha)-diversity in the Dry Evergreen Afromontane vegetation

The result of alpha and beta diversity analysis for the community types of Dry Evergreen Afromontane vegetation are shown in Tables 14 and 15 respectively.

Table 14. Shannon and Weaver diversity indices in the communities of Dry Evergreen Afromontane vegetation

Community	Richness	H'	Shannon and Weaver Evenness
1	58	3.212	0.791
2	64	3.278	0.788
3	85	3.466	0.779
4	61	3.227	0.785
5	62	3.464	0.840

The highest plant diversity and richness occurred in community type 3, but its evenness was least of all community types. The least plant diversity and richness occurred in community type 1, but its evenness was greater than community type 2, 3, and 4.

5.4.4. β (Beta) diversity of Dry EvergreenAfromontane vegetation

Table 15. Beta diversity indices in Dry Evergreen Afromontane vegetation

Community	1	2	3	4	5
1					
2	0.435				
3	0.448	0.391			
4	0.504	0.417	0.486		
5	0.459	0.453	0.517	0.456	

Community types 2 and 3, 2 and 4, and 1and 2 showed the first, second and third least plant species similarity respectively, indicating relatively occurrence of the highest beta diversity between these paired of community types. On the contrary, community types 1and 5, and 3and 5 showed the first and second highest plant species similarity respectively, indicating relatively occurrence of the least beta diversity between these paired of community types (Table 15).

5.5. Soil analysis

5.5.1. Texture, pH, EC and TDS in soil samples of Afroalpine and Dry Evergreen Afromontane regions

The result of textural analyses (Figure 36) reveal that the textural classes of soil samples collected from Afroalpine and Dry Evergreen Afromontane regions were sandy loam, loamy sand, sandy clay loam, clay loam and loam. In general, 98% of soils of the study areas were loamy soil (Appendices 6 and 7).

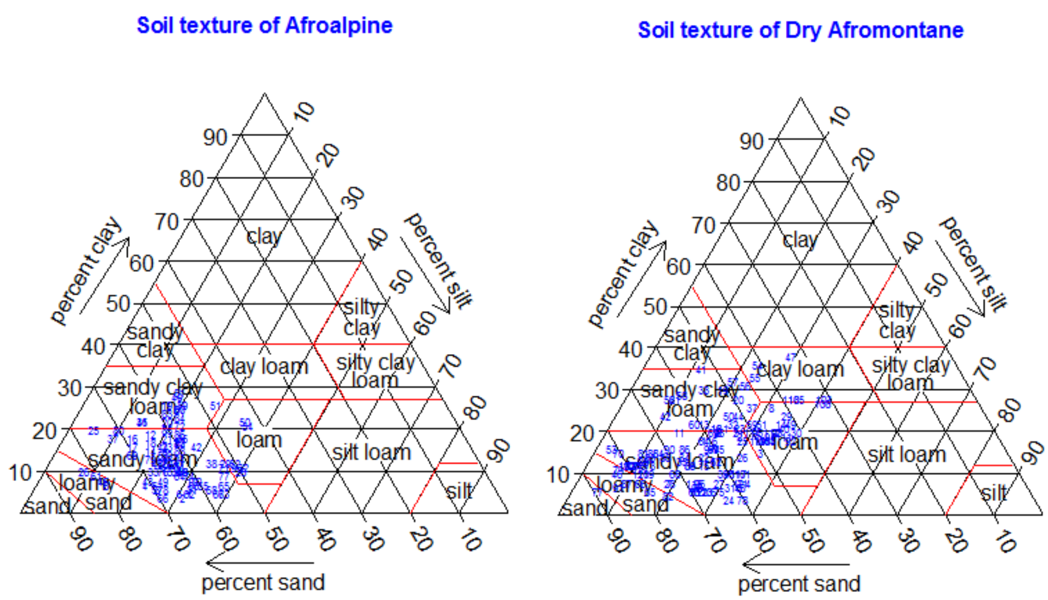

Figure 36. Distribution of soil textures in a standard USDA texture triangle (Left: soil textures of Afroalpine; right: soil textures of Dry Afromontane. The numbers in the triangles represents sample plot from which soil samples were collected.)

The range of soil pH in Afroalpine and Dry Evergreen Afromontane regions were 4.84 – 6.33 (acidic), and 5.66 – 6.5 (acidic to neutral), respectively. The range of Total Dissolved Solutes (TDS) of soil in the Afroalpine region was 18.41 – 146.70 ppm, while 8.67 – 106.32 ppm in the Dry Evergreen Afromontane region. The range of Electric conductivity (EC) of soil in Afroalpine region was 0.03 – 0.24 mS/cm, whereas 0.014 – 0.174 mS/cm in Dry Afromontane region.

5.5.2. Soil textural classes in plant community types

5.5.2.1. Distribution of soil textural classes in the plant community types of Afroalpne vegetation

Figure 37 shows the distribution soil textural classes in the community types of Afroalpine vegetation.

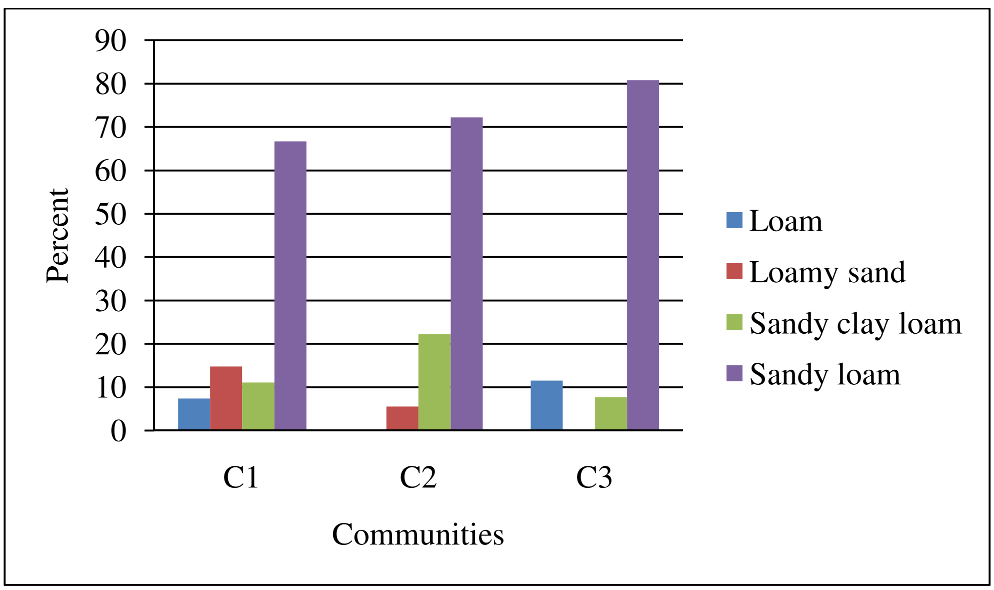

Figure 37. Distribution of soil textural classes in the community types of Afroalpine vegetation (C1= community type 1, C2= community type 2 and C3= community type 3)

Four textural classes were identified from soil samples of Afroalpine region (Figure 38. Only community type 1 had the four textural classes. The content or percentage of sandy loam increased from community type 1 to 3. The dominant texture was Sandy loam. In general, the dominant soil textural class in community types of Afroalpine vegetation was sandy loam, followed by sandy clay loam, loamy sand, and the least soil textural class that occurred in this vegetation was clay loam.

5.5.2.2. Distribution of soil textures in the community types of Dry Evergreen Afromontane vegetation

Figure 38 shows the distribution soil textures in the community types of the Dry Evergreen Afromontane vegetation.

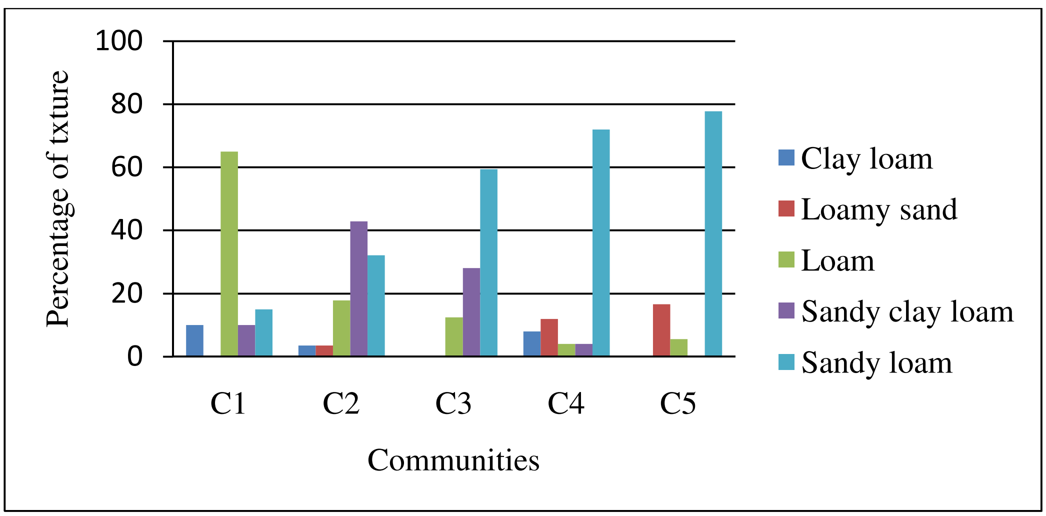

Figure 38. Distribution of soil textural classes in the community types of Dry Evergreen Afromotane vegetation

(C1= community type 1, C2= community type 2, C3= community type 3, C4= community 4 and C5= community 5)

Five textural classes of soils were identified from the soil samples where Dry Evergreen Afromontane vegetation is located (Figure 39. Only community type 2 and 4 had the five textural classes. The percentage of sandy loam increased from community type 1 to 5. The dominant texture in community type 1 was loam, but the dominant texture in community type 2 was sandy clay loam. On the other hand, sandy loam was the dominant texture in community type 3, 4 and 5. In general, the dominant soil textural class in the Dry Evergreen Afromontane was sandy loam, followed by loam, sandy clay loam and loamy sand. The least soil textural class which occurred in this vegetation was clay loam.

Sandy loam was the dominant soil texture in the soil samples of Kurub, Chung, Guble and Darken Mountains. Sandy clay loam was found from soil samples of Kurub, Chung and Kasakan mountains, but not from the samples of Guble and Darken Mountains. Loamy sand was found only from soil samples of Kasakan and Guble mountains. Only two types of texture were recorded from soil samples of Guble Mountain: sandy loam and loamy sand. In general, soil samples of Kurub, Chung and Kasakan Mountains had similar soil textures.

5.6. Ordination

5.6.1. Ordination ofAfroalpine vegetation data

Figure 39 shows important environmental variables which were related to the distribution of plant species and segregation of sample plots of community types of Afroalpine vegetation.

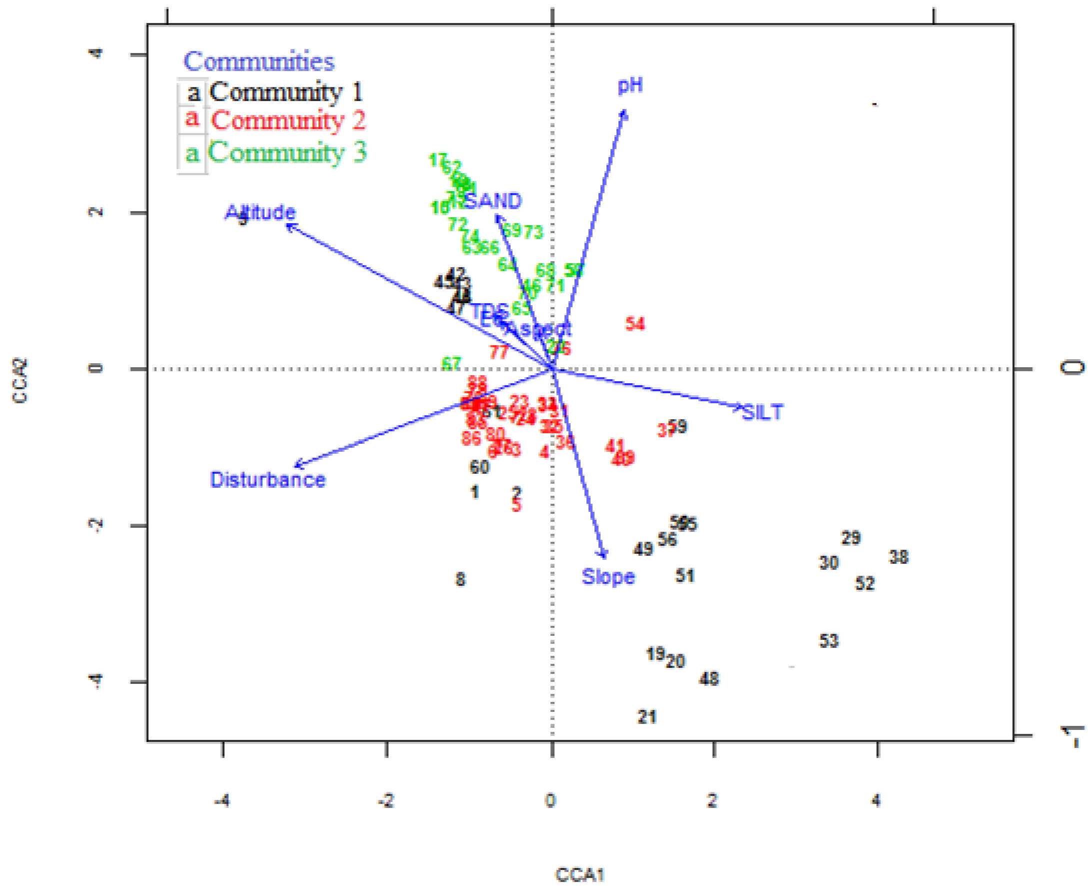

Figure 39. CCA ordination of Afroalpine vegetation, showing the arrangement of sample plots of community types along the vectors of environmental variables

The black, red and green colors represent sample plots of community type 1, 2 and 3 respectively. The distribution of plant species in community type 3 were related with Sand (%). Similarly, the distribution of plant species in community type 2 was related with Disturbance and Slope. Small angle size between two vectors indicates the strength of correlation between the vectors that represent environmental variables.

5.6.2. Ordination for Dry Evergreen Afromontane vegetation

Important environmental variables that influenced the distribution of plant species in community types of Afroalpine vegetation are shown in Figure 40.

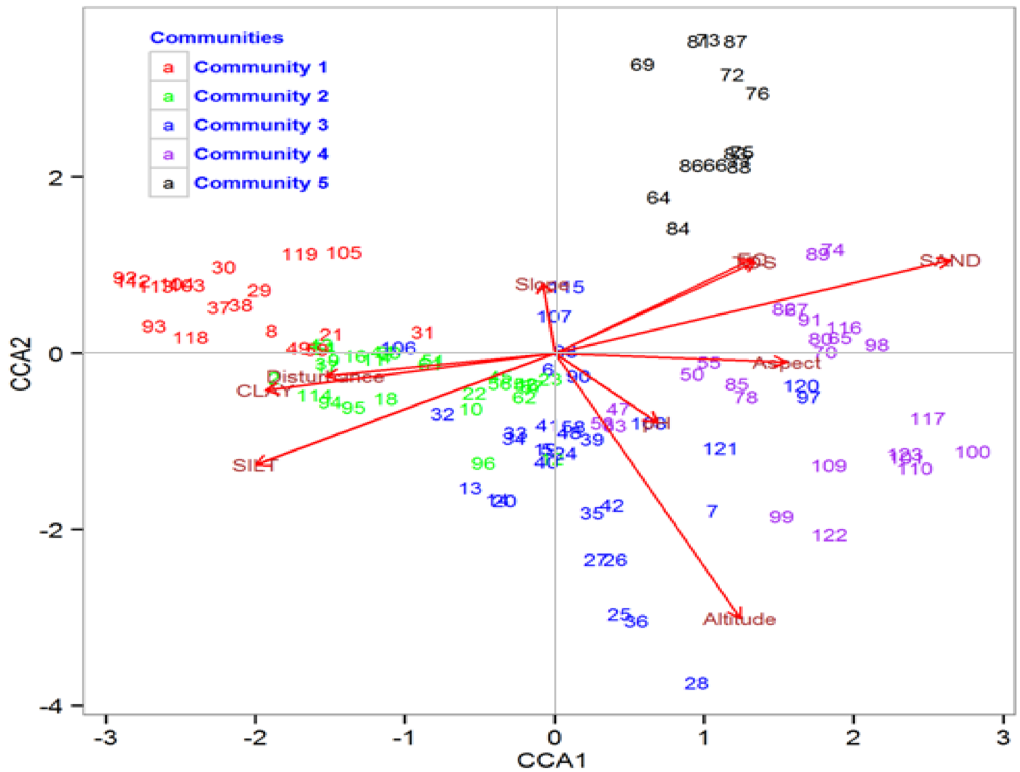

Figure 40. CCA ordination of Dry Evergreen Afromontane vegetation, showing the arrangement sample plots of a community type along the vectors of environmental variables

The red, green, blue, violet and black colors represent sample plots of community type 1, 2, 3, 4 and 5, respectively. The distribution of plant species in community type 3 was related with Altitude and Slope. The distribution of species in community type 4 was related with Sand (%), Aspect and pH. On the other hand, the distribution of plant species in community type 2 was related with Disturbance, Silt (%) and Clay (%).

5.7. Difference between communities with respect to environmental variables

5.7.1. Difference between communities with respect to environmental variables in the Afroalpine vegetation

ANOVA (Appendix 8) shows that the three community types of Afroalpine exhibit significant differences ($P \leq 0.05$) with respect to mean of Altitude, Silt (%), Clay (%) and Disturbance. Based on Tukey's pair-wise test, therefore, the following pairs of community types (C), showed the significant difference. Altitude: (C1, C2) and (C2, C3); Silt (%): (C1, C3) and (C2, C3); Clay (%): (C1, C3) and (C2, C3); Disturbance: (1,3) and (2,3).

5.7.2. Difference between communities with respect to environmental variables in the Dry Evergreen Afromontane vegetation

ANOVA (Appendix 9) shows that the five community types of Dry Evergreen Afromontane vegetation exhibited significant differences ($P \leq 0.05$) with respect to mean of Altitude, Sand (%), Silt (%), clay (%), pH, EC (mS/cm), TDS (ppm) and disturbance. Based on Tukey's pair-wise test, therefore, the following pairs of community types (C), showed the significant difference. Altitude: (C1, C3), (C1, C4), (C2, C3), (2, 4) and (4, 5); Sand (%): (C1, C2), (C1, C3), (C1, C4), (C1, C5), (C2, C4), (C2, C5) and (C3, C5); Silt (%): (C1, C2), (C1, C3), (C1, C4), (C1, C5), (C2, C5) and (C3, C5); Clay (%): (C1, C4) (C1, C5) (C2, C4) and (C2, C5); pH: (2,3); EC (mS/cm) and TDS (ppm): (1,5); Disturbance: (2,4).

5.8. Correlation between environmental variables

5.8.1. Correlation between environmental variables of Afroalpine vegetation

Table 16. Pearson's correlations coefficient and P value between environmental variables of Afroalpine vegetation

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05. Cell Contents: Pearson correlation (upper cell) and P-Value (lower cell). Abbreviations: Alt. = Altitude; Dist. = Disturbance. Units: Altitude (m), Sand (%), Silt (%), Clay (%), EC (mS/cm) and TDS (ppm).

	Alt.	Aspect	Slope	Sand	Silt	Clay	pH	EC	TDS
Alt.									
Aspect	0.01 0.93								
Slope	-0.57 0.00***	0.00 0.99							
Sand	0.18 0.09	-0.09 0.41	-0.32 0.00***						
Silt	-0.34 0.00***	-0.05 0.623	0.19 0.08	-0.64 0.00***					
Clay	0.20 0.06	0.16 0.13	0.14 0.19	-0.38 0.00***	-0.48 0.00***				
pH	-0.06 0.57	0.06 0.55	-0.04 0.72	0.21 0.05*	0.01 0.96	-0.24 0.02*			
EC	-0.07 0.54	0.08 0.49	-0.08 0.43	-0.09 0.42	0.06 0.60	0.03 0.76	-0.03 0.79		
TDS	-0.06 0.56	0.10 0.33	-0.10 0.35	-0.09 0.39	0.07 0.51	0.02 0.84	-0.03 0.80	0.996 0.00***	
Dist.	0.19 0.08	-0.07 0.50	-0.03 0.80	0.17 0.11	-0.36 0.00***	0.24 0.03*	0.02 0.88	-0.206 0.052	-0.217 0.041*

The output of Pearson's correlation test (Table 16) shows significant positive correlation ($P \leq 0.05$) between Sand (%) and pH, Clay (%) and Disturbance, and EC and TDS. On contrary, significant negative correlation occurred between Altitude and Slope, Altitude and Silt (%), Sand (%) and Slope, Silt (%) and Disturbance, Clay (%) and pH, TDS and Disturbance, Sand (%) and Silt (%), Sand (%) and Clay (%), and Silt (%) and Clay (%).

5.8.2. Correlation between environmental variables of Dry Evergreen Afromontane vegetation

Table 17. Pearson's correlations coefficient and P value between environmental variables of Dry Evergreen Afromontane.

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05. Cell Contents: Pearson correlation (upper cell) and P-Value (lower cell). Abbreviations: Alt. = Altitude; Dist. = Disturbance. Units: Altitude (m), EC (mS/cm) and TDS (ppm).

	Alt.	Aspect	Slope	Sand	Silt	Clay	pH	EC	TDS
Alt.									
Aspect	0.19								
	0.03*								
Slope	−0.04	−0.06							
	0.63	0.52							
Sand	0.05	0.14	0.11						
	0.59	0.12	0.21						
Silt	−0.01	−0.11	0.07	−0.63					
	0.95	0.25	0.48	**0.00*****					
Clay	−0.03	−0.01	−0.16	−0.49	0.09				
	0.71	0.93	0.08	**0.00*****	0.32				
pH	0.16	0.04	0.37	−0.03	0.09	−0.01			
	0.07	0.63	**0.00*****	0.79	0.32	0.96			
EC	0.02	0.02	0.06	−0.28	−0.33	−0.29	−0.04		
	0.86	0.80	0.51	**0.00*****	**0.00*****	**0.00*****	0.64		
TDS	0.01	0.02	0.06	0.30	−0.31	−0.31	−0.05	0.99	
	0.91	0.84	0.50	**0.00*****	**0.00*****	**0.00*****	0.62	**0.00*****	
Dist.	−0.35	−0.07	−0.12	−0.06	0.11	0.02	−0.18	−0.17	−0.14
	0.00***	0.44	0.18	0.49	0.25	0.85	**0.05***	0.06	0.13

The output of Pearson's correlation test (Table 17) shows significant positive correlation ($P \leq 0.05$) between Altitude and Aspect, Slope and pH, Sand (%) and TDS, and EC and TDS. On contrary, significant negative correlation ($P \leq 0.05$) occurred between Altitude and Disturbance, Sand (%) and Silt (%), Sand (%) and Clay (%), Sand (%) and EC, Silt (%) and EC, Silt (%) and TDS, Clay (%) and EC, Clay (%) and TDS, Sand (%) and Silt (%), Sand (%) and Clay (%), and Silt (%) and Clay (%)..

5.9. Structures in Dry Evergreen Afromontane vegetation

5.9.1. Stem Density

Trees and shrubs which had circumference ≥ 7.85cm at Brest Height were used to analysis density in community types of Dry Evergreen Afromontane vegetation. A total of 1765 trees and shrubs, belonging to 24 species distributed in 119 Plots (4.76 ha) from which the five community types constituted. Hence, the total stem density of these woody species was 370.8/ha. The five most important woody species which contributed to the highest stem density were *Maytenus arbutifolia* (107.35/ha), *Maesa lanceolata* (95.17/ha), *Acacia abyssinica* (36.55/ha), *Bersama abyssinica* (20.59/ha) and *Pittosporum virdiflorum* (15.34/ha). These five species alone contributed to 74.16% of the total stem density.

5.9.1.1. Distributions of species density in DBH classes

All recorded stem of the woody species were grouped into eight DBH classes (Figure 41). The highest stem density was found between 10.01 and 20 cm DBH class, whereas the least stem density was found in the > 140 cm DBH class. The density of stem decreased as the DBH class size increased above 20 cm. In general, the woody species had high stem density in the lower DBH class and the density gradually decreased with increasing DBH class, representing positively skewed graph.

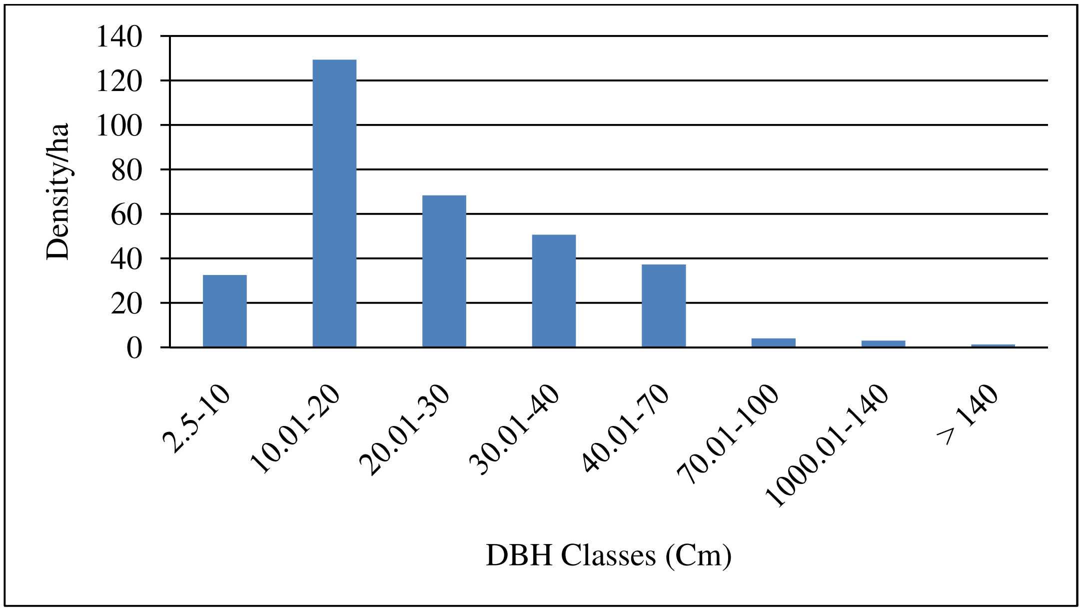

Figure 41. Distribution of stems density in eight DBH classes

Maytenus arbutifolia contributed to the largest number of stems in the DBH class between 2.5 and 10 cm. *Maesa lanceolata*, *Maytenus arbutifolia*, *Gnidia glauca*, *Nuxia congesta*, and *Myrsine melanophloeos* contributed to 79.14% of stems between 10.1 and 20 cm DBH class. *Acacia abyssinica* only attributed 35.16% of stems in the middle DBH classes (30.1– 60 cm). *Schefflera abyssinica* and *Prunus africana* were the only two species which attained DBH class greater than 140 cm.

5.9.1.2. Distribution of stem density in community types

In community type 1, a total of 240 stems, belonging to six woody species were distributed in 20 plots (0.8ha), resulting 300/ha. *Acacia abyssinica* and *Bersama* *abyssinica* contributed to 91.2% (285/ha), whereas *Dombeya torrida*, *Maytenus arbutifolia*, *Maesa lanceolata* and *Erythrina brucei* contributed to the remaining 8.8% (27/ha) (Appendix 10).

In community type 2, a total of 330 stems, belonging to 12 species were distributed in 28 plots (1.12 ha), resulting 293.75/ha. *Maytenus arbutifolia*, *Maesa lanceolata* and *Pittosporum virdiflorum* contributed to 64.44% (151.79/ha), whereas nine other woody species contributed to the remaining 35.56% (141.96/ha).

In community type 3, a total of 760 stems, belonging to 17 species were distributed in 32 plots (1.28 ha), resulting 590.63/ha. *Maytenus arbutifolia*, *Maesa lanceolata* and *Buddleja polystachya* contributed to 87.79% (517.97/ha), whereas fifteen other woody species contributed to the remaining 12.21% (72.66/ha).

In community type 4, a total of 258 stems, belonging to 14 species were distributed in 25 plots (1ha), resulting 247/ha. *Maytenus arbutifolia, Prunus africana,* and *Maesa lanceolata* contributed to 61.13% (151/ha), whereas thirteen other woody species contributed to the remaining 38.87% (96/ha).

In community type 5, a total of 117 stems, belonging to 16 species were distributed in 16 plots (0.56 ha), resulting 314.29/ha. *Maesa lanceolata*, *Canthium oligocarpum* and *Prunus africana* contributed to 57.39% (180.36/ha), whereas seven other woody species contributed to the remaining 42.61% (133.93/ha).

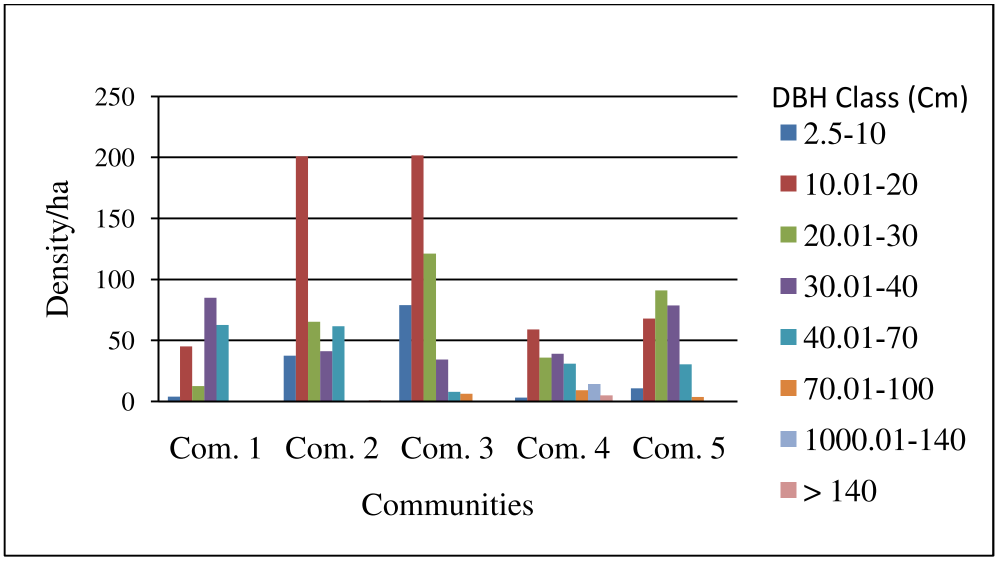

Figure 42. Distribution of stem density of community types in eight DBH classes

The DBH class in which the highest stems density recorded was 10.01-20 cm, occurring in the community type 2 and 3 (Figure 42). Species such as *Maesa lanceolata*, *Maytenus arbutifolia, Gnidia glauca*, *Nuxia congesta*, *Buddleja polystachya*, *Dombeya torrida*, *Allophylus abyssincus* and *Euphorbia amliphylla* were common species occurring in this DBH class. In community type 3 and 5, the number of stems per hectare decreased as DBH increased above 20 cm DBH class. In community type 5, the largest number of stems was occured in 20.01-30 cm DBH class. Species such as *Schefflera abyssinica, Canthium oligocarpum*, *Prunus africana* and *Maesa lanceolata* were common in this DBH class. Only community type 2 and 4 had stems with DBH greater than 140 cm. The two species with diameter exceeding 140 cm were *Schefflera abyssinica* and *Prunus africana.*

5.9.2. Frequency

The five most frequent woody species in the Dry Evergreen Afromontane vegetation were *Maesa lanceolata* (17.02), *Maytenus arbutifolia* (17.02), *Acacia abyssinica* (9.45), *Prunus africana* (7.14) and *Pittosporum virdiflorum* (6.72). These species attributed to 59.86% of the total relative frequency. Analysis of frequency and relative frequency of each woody species in each community type is shown in Appendix 11.

In community type 1, the highest frequency was exhibited by *Acacia abyssinica* 1.05 (RF=50%), *Bersama abyssinica* 0.35 (RF=16.67%) and *Maytenus arbutifolia* 0.15 (RF=16.67). These three woody species alone contributed to 83.34 % of the total relative frequency.

In the community 2, the highest frequency was exhibited by *Maesa lanceolata* 1.04 (RF=21.17%), *Maytenus arbutifolia* 0.82 (RF=16.79%), *Dombeya torrida* 0.75 (RF=15.33%) and *Acacia abyssinica* 0.71 (RF=14.60%). These four woody species alone contributed to 67.89% of the total frequency of this community type.

In community 3, the highest frequency was recorded by *Maesa lanceolata* 0.94 (25.86%), *Maytenus arbutifolia* 0.84 (RF=23.28%), and *Buddleja polystachya* 0.28 (RF=7.76%). These three woody species alone contributed to 56.9% of the total relative frequency.

In the community 4, the highest frequency was exhibited by *Maytenus arbutifolia* 0.8 (RF=22.47%), *Maesa lanceolata* 0.52 (RF=14.6%) and *Prunus africana* 0.52

(RF=14.6%). These six woody species alone contributed to 51.67% of the total relative frequency.

In the community 5, the highest frequency was exhibited by *Schefflera abyssinica* 1.31 (RF=22.11%), *Canthium oligocarpum* 0.75 (RF=12.63%) and *Prunus africana* 0.76 (RF=12.63%). These three woody species alone contributed to 47.37% of the total relative frequency.

5.9.3. Height class distribution

All tree and shrubs species with height ≥ 2.5 m and circumference ≥ 7.85cm at Brest Height were distributed in seven height classes (Figure 43). In general, the number of these woody species decreased with increasing height classes, depicting a positively skewed pattern.

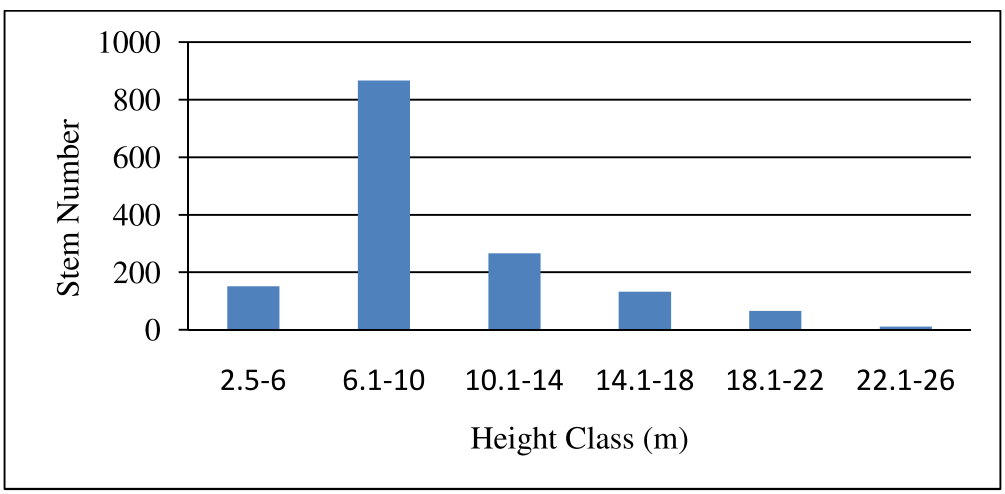

Figure 43. Height class distributions of woody species in Dry Evergreen Afromontane vegetation

5.9.3.1. Height class distribution in community types

Table 18 shows the distribution of woody species in different height classes. The largest number of woody species occurred in 6.1-10 m height class. Community 1 had no any woody species that attained 18 - 26 m height class. Only community type 2, 4 and 5 had tree species which attained in 22.1- 26 m height class. Except community type 2 and 3, all community types had woody species representing all height classes. In general, the number of woody species decreased with increasing height classes.

Table 18. Percentage of woody species distribution within height classes of each community type

Height Class (m)	Com. 1	Com. 2	Com. 3	Com. 4	Com. 5
2.5-60	8.86	8.74	5.23	15.9	22.30
6.1-10	63.29	50.34	74.56	45.8	36.90
10.1-14	22.78	27.59	12.02	10.6	19.60
14.1-18	5.06	5.52	7.84	15.4	14.00
18.1-22	0	7.59	0.35	8.81	6.15
22.1-26	0	0.23	0	3.52	1.12

5.9.3.2. Distribution of woody species in lower, middle and upper storey

Schefflera abyssinica was the highest tree attaining 25.5 m. This species was, therefore, used as standard to classify the height class of the woody species into three height classes.

Table 19. Distribution of woody species in the lower middle and upper storey

Storey	Percent of woody individuals
Lower	52.66
Middle	38.23
Upper	9.11

All of the individuals in the lower storey had height less than 9.1 m (Table 19). Some of the dominant species in this storey were *Maytenus arbutifolia*, *Maesa lanceolata, Buddleja polystachya, Gnidia glauca*, *Allophylus abyssincus* and *Myrsine melanophloeos.* On the other hand, all individuals in the middle storey had height between 9.1 and 17 m. *Acacia abyssinica*, *Maesa lanceolata* and *Dombeya torrida* were few of the representative woody species. Only 5 tree species were distributed in the upper storey. The 5 species were *Albizia schimperiana*, *Schefflera abyssinica*, *Prunus africana*, *Pittosporum virdiflorum* and *Acacia abyssinica.* Most of these woody species had height between 17.1 and 25.5 m.

5.9.3.3. Distribution of woody species in lower, middle and upper story of each community type

Table 20. Percentage and density of woody species in lower, middle and upper storey of each community type

	Percentage			**Density/ha**		
	Lower Storey	Middle Storey	Upper Storey	Lower Storey	Middle Storey	Upper Storey
Com. 1	7.04	92.96	0	12.50	165.00	0
Com. 2	45.16	45.18	9.65	183.90	183.93	39.29
Com. 3	65.92	26.22	4.86	310.20	117.97	21.88
Com. 4	55.07	23.79	21.14	125.00	54.00	48.00
Com. 5	52.51	34.08	13.41	167.90	108.93	42.86

In community type 1and 2, woody species in the middle storey were denser than woody species in lower and the upper stories. More than 50% of woody species of community type 3, 4 and 5 were distributed in lower storey (Table 20).

5.9.4. Basal area (BA)

The total basal area of woody species in the Dry Evergreen Afromontane vegetation was 28.65 m^2/ha . Of the total basal area, 24.9 m^2/ha (86.9%) was accounted by seven woody species including *Schefflera abyssinica*, *Acacia abyssinica*, *Maesa lanceolata*, *Prunus africana*, *Maytenus arbutifolia*, *Pittosporum virdiflorum* and *Dombeya torrida* (Table 21).

Table 21. Basal area, density and percent of the seven woody spp. in Dry Evergreen Afromontane vegetation

(BA=Basal Area; RBA= Relative Basal Area; RD= Relative Density)

S. No.	Tree Spp.	BA (m^2)	BA (m^2/ha)	RBA (%)	Density (stem no./ha)	RD (%)
1	*Schefflera abyssinica*	29.23	6.14	21.4	5.462	1.47
2	*Acacia abyssinica*	26.84	5.64	19.7	36.55	9.86
3	*Maesa lanceolata*	14.89	3.13	10.9	95.17	25.7
4	*Prunus africana*	13.58	2.85	9.96	14.08	3.8
5	*Maytenus arbutifolia*	12.92	2.71	9.48	107.4	29
6	*Pittosporum virdiflorum*	11.24	2.36	8.25	15.34	4.14
7	*Dombeya torrida*	9.77	2.05	7.16	9.034	2.44
	Total	**118.46**	**24.9**	**86.9**	**283**	**76.3**

5.9.4.1. Distribution of BA in community types

Figure 44 and Appendix 12 show the distribution of basal area of woody species in each community type. The highest basal area was recorded in community type 4, followed by community type 1, 5 and 3. The least basal area was recorded in community type 2.

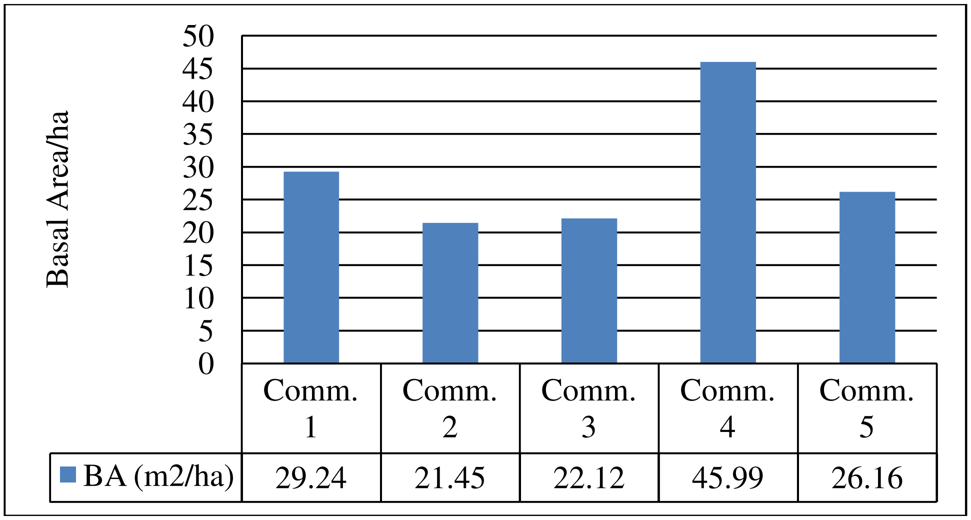

Figure 44. BA (m^2/ha) of woody species in Dry Evergreen Afromontane vegetation

The five most important woody species which contributed to highest basal area per hectare in the community types are listed in Table 22. In all community types, the highest BA/ha was recorded in the > 20 cm DBH class, whereas the least BA/ha was recorded in the 2.5- 10 cm DBH class. Woody species in community type 5 exhibited relatively the highest BA/ha per small density in all DBH classes.

Table 22. Basal area and density of the five most important woody species in each community type

Woody species	BA (m^2/ha)	%	Density (Indv./ha)	%
Community type 1				
Acacia abyssinica	24.64	84.3	173.8	57.92
Dombeya torrida	2.90	9.93	12.5	4.17
Maytenus arbutifolia	1.51	5.17	10	3.33
Allophylus abyssincus	0.10	0.34	2.5	0.83
Bersama abyssinica	0.08	0.27	111.3	37.08
Community type 2				
Acacia abyssinica	5.62	26.21	23.21	7.88
Pittosporum virdiflorum	5.15	24.02	37.5	12.73
Dombeya torrida	3.48	16.24	21.43	7.273
Maytenus arbutifolia	3.27	15.25	79.46	26.97
Nuxia congesta	1.50	7.01	36.61	12.42
Community type 3				
Maesa lanceolata	7.74	34.98	231.3	38.95
Maytenus arbutifolia	4.93	22.30	253.1	42.63
Buddleja polystachya	3.77	17.02	1.563	5.13
Schefflera abyssinica	1.40	6.33	1.563	0.26
Gnidia glauca	1.12	5.05	33.59	5.66
Community type 4				
Schefflera abyssinica	26.04	56.61	22	8.53
Prunus africana	10.09	21.93	37	14.34
Pittosporum virdiflorum	2.77	6.03	20	7.75
Dombeya torrida	2.41	5.23	9	3.49
Maytenus arbutifolia	1.55	3.37	82	31.78
Community type 5				
Prunus africana	5.19	19.82	39.29	12.43
Pittosporum virdiflorum	3.80	14.53	12.5	3.95
Maesa lanceolata	3.60	13.77	78.57	24.86
Allophylus abyssincus	2.63	10.03	26.79	8.48
Schefflera abyssinica	2.51	9.58	3.57	1.13

Table 23. Distribution of Density and Basal Area of woody species in DBH classes

	<10 cm		**10-20 cm**		**>20 cm**	
	Density (Indv./ha)	BA (m^2/ha)	Density (Indv./ha)	BA (m^2/ha)	Density (Indv./ha)	BA (m^2/ha)
Com.1	3	3.75	36	45	128	160
Com.2	42	37.5	225	200.89	189	168.75
Com.3	101	85.59	259	219.49	2116	1793.22
Com.4	35	35	57	57	135	135
Com.5	27	48.21	38	67.86	114	203.57

5.9.5. Population structure

Population structure analysis was employed to demonstrate the dynamics of selected woody species in the Dry Evergreen Afromontane vegetation. Four distribution patterns were identified in the output of population structure analysis. These were Inverted J-shaped, Gaussian-curve, J-shaped and U-shaped (Figure 45 A-D).

The inverted J-shaped distribution pattern was represented by *Maytenus arbutifolia* (Figure 45 A). In this pattern, the lower DBH classes had high density of woody species and the density gradually decreased with increasing DBH classes. Woody species included in this pattern were *Allophylus abyssincus*, *Bersama abyssinica*, *Buddleja polystachya*, *Euphorbia amliphylla*, *Gnidia glauca*, *Maesa lanceolata*, *Maytenus arbutifolia* and *Nuxia congesta.*

The Gaussian-curve distribution pattern was represented by *Prunus africana* (Figure 45 B). In this pattern, the lower DBH classes had low density of woody species and the density gradually increased towards middle DBH classes, and then decreased towards the highest DBH classes. Woody species included in this pattern were *Acacia abyssinica*, *Croton macrostachyus* and *Myrsine melanophloeos*.

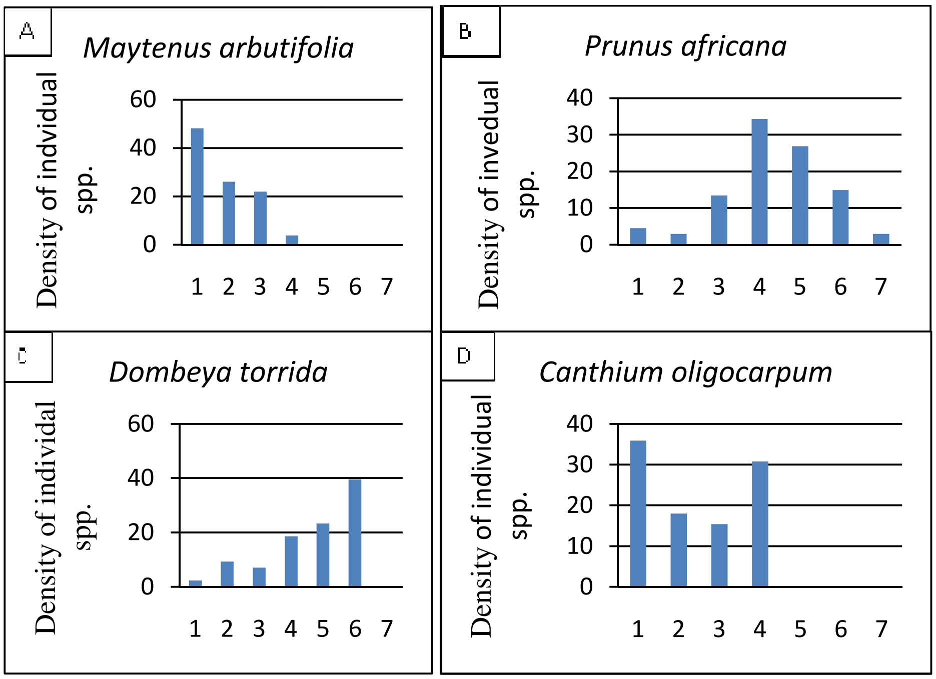

Figure 45. A-D Population structure patterns of selected woody species in the Dry Evergreen Afromontane vegetation

(1 = 2.5 - 10 cm; 2 = 10.1 - 20 cm; 3 = 20.1 - 30 cm; 4 = 30.1 - 40 cm; 5 = 40.1 - 60 cm; 6 = 60.1 - 100 cm; 7 = > 100 cm)

The J-shaped distribution pattern was represented by *Dombeya torrida* (Figure 45 C). Woody species in this group had low density in the lower DBH class and the density gradually increased with increasing DBH classes. *Schefflera abyssinica* belongs to this distribution pattern.

The U-shaped distribution pattern was represented by *Canthium oligocarpum* (Figure 45 D). The pattern shows that high density of woody species occurred in the lowest and highest DBH classes, but the density was low in the intermediate DBH classes. Woody species included in this pattern were *Albizia schimperiana* and *Dovyalis abyssinica*.

5.9.6. IVI (Important Value Index)

IVI assessment at ageneral level shows that the seven woody species which had the least IVI in the Dry Evergreen Afromontane vegetation were *Teclea nobilis, Erythrina brucei, Bersama abyssinica, Croton macrostachyus, Ekebergia capensis, Albizia schimperiana* and *Euphorbia amliphylla*. On the other hand, IVI assessment at community level (Table 24 and Appendix 14) shows the three woody species which had least important value index in each community types.

Table 24. The three woody species with least Importance Value Indices in each community type

Com. 1	**IVI**	**Com. 4**	**IVI**
Nuxia congesta	2.381	*Galiniera coffeoides*	1.75
Erythrina brucei	5.595	*Croton macrostachyus*	2.47
Allophylus abyssincus	8.314	*Euphorbia amliphylla*	3.13
Com. 2	**IVI**	**Com. 5**	**IVI**
Erythrina brucei	0.88	*Galiniera coffeoides*	2.198
Galiniera coffeoides	1.03	*Hypericum revolutum*	2.879
Allophylus abyssincus	2.27	*Acacia abyssinica*	4.109
Com. 3	**IVI**		
Hypericum revolutum	2.08		
Rosa abyysinica	2.25		
Galiniera coffeoides	2.28		

5.10. Regeneration

A total of 1935 seedlings, 1795 saplings and 1765 matured individuals of woody species were recorded. Figure 46 and Appendix 16 show the density (number/ha) of seedlings, saplings and matured individuals of woody species in the five community types.

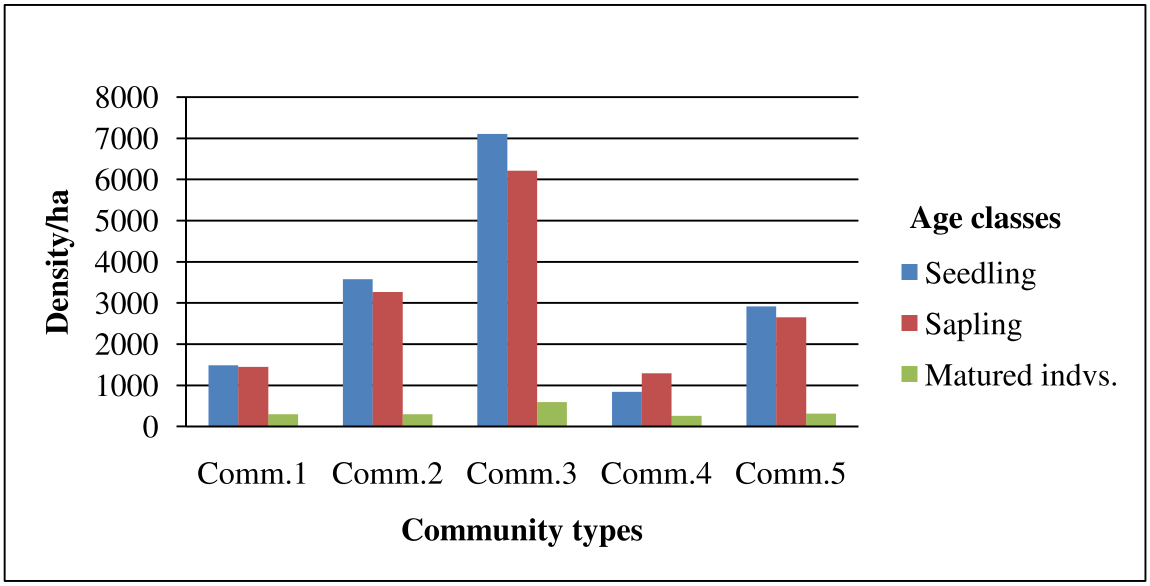

Figure 46. Age class distribution of woody species in the Dry Evergreen Afromontane vegetation

For purposes of proposing conservation priority, the number of seedlings/ha of the woody species has been categorized into three groups. Woody species having seedling 0 or 1/ha were categorized under group I. Thus, *Albizia schimperiana*, *Croton macrostachyus*, *Ekebergia capensis*, *Erythrina brucei*, *Euphorbia amliphylla*, *Gnidia glauca* and *Myrsine melanophloeos* were categorized under group I.

Woody species having 1 to 15/ha seedlings were categorized under group II. In this case, *Teclea nobilis*, *Nuxia congesta*, *Dovyalis abyssinica*, *Rosa abyysinica*, *Galiniera coffeoides* and *Schefflera abyssinica* were categorized under group II.

Woody species with seedlings greater than 15/ha were categorized under group III. Hence, *Hypericum revolutum*, *Prunus africana*, *Canthium oligocarpum, Acacia abyssinica*, *Dombeya torrida*, *Buddleja polystachya*, *Bersama abyssinica*, *Allophylus abyssincus*, *Pittosporum virdiflorum*, *Maytenus arbutifolia* and *Maesa lanceolata* were categorized under group III. Species categorized under group I and II need conservation priority.

5.11. Phytogeographical comparison

Composition of floristic similarity was made between the Choke-Koso Ber Range and some other similar mountains in Ethiopia (Table 25)

A total of 243 plant species, belonging to 177 genera and 71 families were recorded in the natural vegetation of Choke-Kosso Ber Mountain Range. The mountain range includes Afroalpine and Dry Evergreen Afromontane vegetation. One handred fourty one plant species, belonging to 103 genera and 40 families were recorded in the Afroalpine vegetation of the Choke Mountain, while 147 species, belonging to 118 genera and 62 families were recorded in the Dry Evergreen Afromontane vegetation (Kurub, Chung, Kasakan, Guble and Darken Mountains).

Getinet Masresha (2014) recorded a total of 532 plant species, belonging to 328 genera and 102 families from the vegetation of Simien Mountains National Park, located in North Gondar, Amhara zone, North Ethiopia. The mountains include Dry Evergreen Afromontane and Afroalpine vegetations which are situated between 2000 and 4530 m altitudes. The number of common plant species to the vegetation of Simien and Choke-Koso Ber Mountain Range was 158. The output of Sorenson's floristic similarity index of the two comparable Mountains was 52%.

Aramde Fetene *et al*. (2010) recorded a total of 142 plant species belonging to 122 genera and 56 families in Menagesha Suba vegetation. This Dry Evergreen Afromontane vegetation is located in central part Ethiopia, 30 km south west of Addis Ababa, situating between 2200 and 3000 m altitudes. There were 51 species common to the Dry Evergreen Afromontane vegetation of Menagesha Suba and Choke-Koso Ber Mountain range. The Sorenson's floristic similarity index of the vegetation of the two mountains, without considering the afroalpine vegetation of the Choke-Koso Ber mountain range, was 39%.

Tamiru Demsis (2015) recorded a total of 298 plant species, belonging to 222 genera and 85 families in the vegetation of Gurage Mountains, located in Gurage zone, Southern National, Nationalities, Central Ethiopia. The mountains include Dry Evergreen Afromontane and Afroalpine vegetations which extended between 2291 and 3588 m. The number of common plant species and the Sorenson's floristic similarity index of the vegetation of Gurage and Choke-Koso Ber Mountain Range were 81 and 30%, respectively.

Menassie Gashaw (1994) recorded 65 species in the vegetation of Sanettie plateaus, located in Bale zone, Oromya region, Southeast Ethiopia. The Sanetti Plateau is the major Afroalpine vegetation of Bale Mountains, situated between 3,800 and 4,377 m. The number of common species to the Afroalpine vegetation of Senettie plateau and Choke-Koso Ber Mountain range without considering the Dry Evergreen Vegetation of Choke-Koso Ber mountain Range, was 32 species. The Sorenson's floristic similarity index of the two Afroalpine vegetations was 31%.

Kitessa Hundera *et al.* (2007) recorded a total of 113 plant species belonging to 95 genera and 55 families in vegetation of Dodola on the Bale Mountains, located in Bale zone, Oromya region, Southeast Ethiopia. This Dry Evergreen Afromontane vegetation extends between 2500 and 3500 m altitudes. The number of common species and Sorenson's floristic similarity index of both Dry Evergreen Afromontane vegetation of the Dodola and the Choke-Koso Ber Mountain range were 51 and 39%, respectively.

Table 25. Floristic similarity beween the study area and some others mountains in Ethiopia

Author	**Mountain**	**Altitudnal range (m)**	**Vegetation type**	**No. of species recorded**	**Common Species to study area**	**Sorenson's Similarity Index**
Getinet Masresha (2014)	Simien Mountains National Park	2000 - 4530	Dry Evergreen Afromontane and Afroalpine	532	158	52%
Aramde Fetene *et al*. (2010)	Menagesha Suba	2200 - 3000	Dry Evergreen Afromontane	142	51	39%
Tamiru Demsis (2015)	Gurage Mountains	2291 - 3588	Dry Evergreen Afromontane and Afroalpine	298	81	30%
Menassie Gashaw (1994)	Sanettie plateaus on the Bale Mountains	3,800 - 4,377	Afroalpine	65	32	31%
Kitessa Hundera *et al.* (2007)	Dodola on the Bale Mountains	2500 - 3500	Dry Evergreen Afromontane	113	51	39%

CHAPTER SIX

6. Discussion

6.1. Floristic composition

The total number of plant species recorded in the study area was 243. The following were some of the expected main factors that limited the number species in the study area. First, species richness decreases with increasing altitude, largely in proportion to the available land area (Körner, 2000). Similarly the number of species decreased with increasing altitude along the mountains of the study area; especially the situation was remarkable in Choke Mountains, as it had been inspected from the collected data. The Second factor was anthropogenic impacts. In general, the study areas were situated between 2440 and 4080 m altitudes. In the case of Choke Mountain, for instance, no plant specimen was collected between 2707 and 3440 m altitudes (733 m altitudinal gap) because the natural vegetation within this altitudinal range has been converted to farmland and plantation.

Regarding the growth habit, 70% of the species in the study area were herbaceous and the stature of the vegetation decreased with increasing altitude. White (1983) described the patterns and adaptation of mountains vegetation as the following. 'On nearly all African mountains, the vegetation diminishes in stature (decrease in size or height) from the lower slopes to the summit', but this regularity is often modified by local features of aspect, exposure, incidence of frost, depth of soil and by overall patterns of climate dependant on the size and configuration of the mountain in relation to distance from the sea and others source of moisture, that generalized sachems of zonation. These environmental factors might cause the gradual diminishing in size of the vegetation and thus decreasing the number of tree and shrub species as altitude increased. Almost all of the trees species, for instance, were recorded in the Dry Evergreen Afromontane vegetation, even though only one tree species was recorded in Afroalpine vegetation. In addition, disturbance such as clearing trees and shrubs for grazing lands demand, selective cutting and fire woods collecting were other factors which could encourage the growth and distribution of herbs in the study areas.

Floristically, Afroalpine vegetation was less similar to Dry Evergreen Afromontane vegetation. Less floristic similarity might be associated with some plant adaptation to the following extreme environmental factors. Total atmospheric pressure, temperature and air density decrease with increasing altitude, whereas wind velocity, radiation under cloudless sky and precipitation increase with increasing altitude. The air pressure, such as partial pressures of oxygen and carbon dioxide, decreases by about 10% for every kilometer of elevation (Körner and Ohsawa, 2005; Körner, 2007; Barry, 2008). According to Hedberg (1964) and Beniston (2003), several of plant species in high mountains have very conspicuous morphological and physiological adaptations to withstand their extreme environmental variables. Hedberg (1964) recognized five distinct life forms adapted to tropical Alpine conditions. Based on his recognition, the Afroalpine vegetation of this study area consisted of giant rosette plants such as *Lobelia rhyncopetalum*; tussock grasses such as *Festuca macrophylla*; acaulescent (stemless) rosette plants such as *Ranunculus areophytus*, *Sagina abyssinica*, *Haplocarpha schimperi*, *Haplocarpha rueppellii*, *Diantheseris schipmperi* and *Cotula cryptocephala;*

cushion plants such as *Helichrysum citrispinum* and Sclerophyllous shrubs. These plant species were restricted in the Afroalpine region of the study area.

6.1.1. Endemic plant species in the vegetation of Choke – Koso Ber Mountain rage

About 13.58% of the total species recorded in the Choke–Kosso Ber Mountain range were endemic plants to Ethiopia. Some authors give details why mountains ecosystems often possess many endemic plant species. Ecologically, the Afroalpine biota is indeed an island biota and the high mountain summits protrude as isolated temperate islands above the warm surrounding plains (Hedberg, 1961). Many species remain isolated at high elevations compared to lowland vegetation communities that can provides unique opportunities to speciation in connection with adaptation to extreme environmental conditions (Hedberg, 1975; Beniston, 2006).

6.1.2. New plants records for Gojjam Floristic Region

According to the Map of the Floristic Regions of Ethiopia and Eritrea, the vegetation of Choke-Koso Ber mountain range is located in Gojjam (GJ) floristic region. Out of the total species recorded in the mountain range, 49 species have not been recorded in the GJ floristic region. The data indicated that the vegetation of Choke-Koso Ber mountain range was not studied in detail and that the plant specimens were not exhaustively recorded and collected. The data may be considered as a contribution for improving the flora books.

6.2. Classification

The study area included Afroalpine and Dry Evergreen Afronontane vegetation types. Thus, two cluster analyses were purposely applied.

6.3. Plant diversity in Choke – Koso Ber Mountain range

One of the reasons for the occurrence of high diversity in the study area was more likely associated with the occurrence of diverse habitats and dominance of loamy texture of the soil in the study area. Species diversity is generally higher in mountain areas than in lowlands as a result of diverse habitat coupled with sharp altitudinal gradients in temperature, precipitation (Regato and Salman, 2008). Soils having sandy loam, or loam-textured surface soils, are better suited for most plants because these soils are generally more fertile, contain more organic matter, have higher cation exchange and buffer capacities, retain moisture and nutrients, and permit less rapid movement of air and water (Brown, 2003).

6.3.1. Alpha diversity in the communities types of Afroalpine vegetation

The range of Shannon and Weaver diversity index in the Afroalpine vegetation was 2.7 -3.9, indicating the occurrence of high diversity. Shannon and Weaver index (H') has probably been the most widely used index in community Ecology (Zerihun Woldu, in press) and biologically realistic H' values range from 0 (only one species present with no uncertainty as to what species each individual will be) to about 4.5 (high uncertainty as species are relatively evenly distributed). In theory, the H' value can be much higher than 4.5, although most real world estimates of H' range from 1.5 to 3.5.

The first highest diversity, richness and evenness occurred in community type 1 (*Koeleria pyramidata - Trifolium cryptopodium* type). The plots of this community type were distributed within altitudinal range of 3430 and 4028 m. Diversified environmental niches, such as grassland, semi-wetlands, wetlands and four soils textural classes were recorded in this community type. The textural classes were sandy loam, sandy clay loam, loamy sand and loam. Moreover, moderate disturbance was recorded in this type. Howe (1999) mentioned that grazers tend to increase diversity by reducing dominant vegetation. Hence, the presence of high environmental diversity, high altitudinal range and moderate disturbance might cause to highest plant diversity, richness and evenness.

The second highest diversity and richness occurred in community type 2 (*Euryops pinifolius- Alchemilla abyssinica* type), even though its evenness was less than community type 3. This community was heavily disturbed by livestock and Man. *Euryops pinifolius* was highly dominant and widely distributed species in this community. The number of plots in this community type was greater than community type 1, but its diversity index was less than community type 1.This community type also included rocky, stony and degraded habitats in which *Helichrysum citrispinum* grew profusely.

The least diversity and richness occurred in community 3 (*Erica arborea* type), but its evenness was greater than community type 2. The plots in this community type were distributed between 3450 and 3814 m altitudes. The type was distinct because it was over dominated with *Erica arborea*, well protected and less disturbed. The evenly distribution of *Erica arborea* may have dominated the growth and diversity of other plant species. Selective cutting and clearing on this shrub was intensive at the peripheral areas of the community. As a result, some plant species such as *Echinops longisetus* could get the opportunity to grow and became dominant.

In general, diversity and richness tended to decrease with increasing altitude. Evenness was relatively highest at the middle of the Mountains. Community types that had largest number of sample plots, highest altitudinal range and moderate disturbance was found to have the highest species diversity, richness and evenness.

6.3.2. Beta diversity in Afroalpine vegetation

Beta diversity is the rate of change of community along an ecological gradient. Thus, it measures the change in diversity of species among set of communities by calculating the number of species that are not the same in two communities. A high β–diversity index indicates a low level of similarity, while a low beta diversity index shows a high level of similarity (Zerihun Woldu, in press). Accordingly, community types 1and 2 exhibited the least species turnover (change) since they shared 46% common plant species. On the contrary, community types 1and 3, and 2 and 3 exhibited the least species turnover since they shared more than 61% common plant species. In general, species turnover tended to increase with increasing altitude.

6.3.3. Alpha diversity in the plant community types of Dry Evergreen Afromontane vegetation

The first highest richness and diversity occurred in community 5 (*Maesa lanceolata - Maytenus arbutifolia* type) but its evenness was less than community types 2, 3 and 5. In this type the plots were distributed between 2505 and 2735 m altitudes. The intermediate (moderate) disturbance hypothesis (Loucks, 1970; Grime, 1973; Connell, 1978; Huston, 1994; Tilman, 1983 cited in Pausas and Austin, 2001) suggests that species richness reaches a maximum at some 'intermediate' level of disturbance. The vegetation of this community type was subjected to intermediate (moderate) disturbance by livestock and selective tree cuttings. As the result, some space was left in which many species could find the opportunity to grow. *Maytenus arbutifolia* was one of the dominant species in this community type. This species had no dense canopy so that many herbaceous and woody plant species could also grow under it. The output of CCA depicts that the distribution of species in this community type had strong correlation with Altitude. The plots belonging to this community type were distributed within highest altitudinal range (230 m).

The second highest diversity and the first highest evenness occurred in community 5 (*Prunus africana - Allophylus abyssincus* type), but its richness was less than community type 3 and 2. In this type, the plots were distributed within 2480 and 2685 m altitudes. The richness might be associated with its highest altitudinal range (205m). In addition, the type included both grasslands and forests which were under moderate and low environmental disturbances.

The least diversity, richness and evenness indices were recorded in community 1 (*Acacia abyssinica - Bersama abyssinica* type). In this type, the plots were distributed within altitudinal range between 2530 and 2650 m. Most of the sample plots were found at the bottom of the mountain forests. In most plots of this community type, the flat crown of the matured Accacia trees formed closed canopies. Under these trees, shrubs such as *Brucea antidysenterica, Bersama abyssinica, Vernonia auriculifera* and *Vernonia myriantha* were the dominant species. The output of CCA depicted that the distribution of species in this community type was correlated with disturbance. Herbaceous species under large trees and shrubs of the type were heavily disturbed by livestock. Since the community type was adjacent to farmlands and grazing areas, many farm animals aggregate in the area for grazing and to find shelter during warm and sunny days. Here, Seedling and sapling of many plant species were highly disturbed.

6.3.4. Beta diversity in Dry Evergreen Afromontane vegetation

Community types 1and 2, 1and 3, 1and 5, 2 and 3, 2 and 4, 2 and 5, 3and 4, and 4and 5 shared less than 50% common plant species, indicating relatively high species turnover, whereas community types 1 and 5, and 3 and 5 shared greater than 50% common plant species, indicating relatively the least species turnover. Unlike the other community types, community type 5 consisted of four plots of grasslands. In general, species turnover (β–diversity) increased with increasing altitude.

6.4. Community-Environment Relation

6.4.1. Ordination

The outputs of CCA show that influential environmental variables that had influence on species distribution in the plant community types of the study areas were Altitude, Aspect, Slope, Sand (%), Silt (%), Clay (%), pH, EC, TDS and Disturbances. The possible influence of the environmental factors (trajectories) on the Afroalpine and dry Evergreen Vegetation types are given below.

A. Altitude: In Dry Evergreen Afromontane vegetation, altitude influenced the plant species distribution and sample plots segregation of community type 3. Total atmospheric pressure, temperature and air density decrease with increasing altitude, whereas wind velocity, radiation and precipitation increase with increasing altitude. The air pressure, such as partial pressures of oxygen and carbon dioxide decreases by about 10% for every kilometer. These factors have considerable influence on the growth and distribution of plants (Hedberg, 1964; Körner and Ohsawa, 2005; Körner, 2007; Barry, 2008). Thus, the above mentioned factors might potentially influence the species distribution and sample plots segregation of community type 3 in the Dry Evergreen Afromontane vegetation.

B. Aspect: Aspect was related with the plant species distribution and sample plots segregation of community type 3 in Afroalpine and community type 4 in Dry Evergreen Afromontane vegetation types. As a topographic variable, aspect affects the amount and daily cycle of solar radiation received at different times of the year, and has an influence on the microclimate, especially air temperature, humidity, and soil moisture (Rosenberg *et al*. 1983). The influence of aspect on soil moisture content has significant relationships with plant distribution (Goldin, 2001). Aspect has a profound effect on species composition, size class distribution, dry biomass, basal area, air temperature, relative humidity and evapotranspiration (Fekedulegn Desta, 2004). Hence, these factors might relate with the plant distribution and sample plots segregation of community type 3 in the Afroalpine and community 4 in the Dry Evergreen Afromontane vegetations.

C. Slope: There was partial relationship between slope and plant species distribution of community type 2 of Afroalpine region. The orientation of slope influences the precipitation input, the temperature regime, the risk for wind impact and the character of humus formed (FAO, 2006). Slope is an important environmental element, which influences run-off and drainage, thereby, determining the nutrient, depth and water content of the soil (Teshome Sormessa *et.al.* 2004). Slope influences the composition, structure, density of plant communities, tree canopy and diameter at breast height as shown in Albaba (2004). According to Auslander *et al*. (2003), in the northern hemisphere, south-facing slopes may receive as much as six times more solar radiation than north-facing slopes (NFS). Thus, the SFS has a more xeric environment, that is, warmer, drier and a more variable microclimate, than the mesic NSF. These factors might relate with distribution of the species in some sample plots of community 2 of the Afroalpine vegetation.

The degree of the slope also greatly affects how much water infiltrates the soil and subsequent runoff and erosion, which influence both soil type and growth of vegetation

(Butler *et al*., 1986). Because plants are affected by these environmental requirements they order themselves into specific community types along an environmental gradient (Thomas and Anderson, 1993). Although the work of Auslander (2003) applies to high latitude areas, tropical areas, the same can be true to s light degree in tropical areas such as the current study site.

D. Texture: Soil texture is an important soil parameter that affects site quality. It influences the nutrient supplying ability of soil solids, soil moisture and air relations, and root development (Spurr and Barnes, 1980). About 23% and 71% of soil texture in community type 3 of Afroalpine vegetation were Sandy clay loam and Sandy loam respectively.Sandy soils tend to be low in organic matter content, low in ability to retain moisture and nutrients, low in cation exchange and buffer capacities, and rapidly permeable water and air (Brown, 2003). Thus, the above explanation suggests that the percentage of sand in a soil texture might relate with the plant species distribution of community type 3 of Afroalpine.

Brown (2003) reckoned the important soil texture types that fine-textured soils generally are more fertile, contain more organic matter, have higher cation exchange and buffer capacities, are better able to retain moisture and nutrients, and permit less rapid movement of air and water. Soils with loam-textured surface are better suited for most plants. Thus, percentage of silt and clay might relate with the plant species distribution in the community type 2 of Dry Evergreen afromontane vegetation.

In general, loamy soil was the dominant texture in the study area, accounted for 98%. O'Geen (2006) noted that medium-textured soils (loamy soil) tend to be most erodible because they have high amount of silt and fines sands. Therefore, the soils of the study areas had highest erodible property.

E. pH: The pH range normally found in soils varies from 3 to 9 (Williston and LaFayette 1978 cited in Londo *et al*., 2006). Descriptive terms commonly associated with certain ranges in pH are extremely acidic (pH < 4.5), very strongly acidic (pH 4.5 - 5.0), strongly acidic (pH 5.1- 5.5), moderately acidic (pH 5.6 - 6.0), slightly acid (pH 6.1- 6.5), neutral (pH 6.6-7.3), slightly alkaline (pH 7.4 - 7.8), moderately alkaline (pH 7.9 - 8.4), strongly alkaline (pH 8.5 - 9.0), and very strongly alkaline (pH > 9.1) (Foth and Ellis, 1997). In general, soil samples of this study area, therefore, fall in the range of very strongly to slightly acid (Appendix 5 and 7). The soil pH of community type 3 in the Afoalpine region was strongly to slightly acidic, while the soil pH of community type 4 in the Dry Evergreen Afromontane vegetation was moderately to slightly acid. This might be caused by the availability of high organic matter content. It has been reported that forest soils should be slightly acidic for nutrient supply to be balanced (Leskiw, 1998). The plant species distribution and sample plots segregation of community type 3 in Afroalpine and community 4 in Dry Evergreen Afromontane vegetation might relate with soil pH in some extent.

F. EC/TDS: High salinity may reduce moisture availability to plants and result in plant dehydration due to osmotic effect (Ayers and Westcot, 1985). Reduced moisture availability diminishes nutrients uptake, which may further restrict plant growth. High level of salt can result in toxicity and nutrient imbalance (Marschner, 1986). According to Dahnke and Whitney (1988), a soil EC with the range of 0.0 - 2.0 mS/cm is categorized under non saline. The EC range of all soil samples of community 3 of Afroalpine was 0.03 – 0.24 mS/cm, indicating the soils were none saline. As the result, the non saline of the soil may be important for the species distribution and segregation of community type 3 in the Afroalpine region.

6.6. Variation between community types with respect to environmental variables and correlations between the environmental variables

Analysis of variance (ANOVA) and Tukey's pair-wise test were computed to test if there is any significant variation among the community types with respect to any mean of environmental variable. Pearson's product-moment correlation was also calculated to test the correlations between the environmental variables.

There was significant negative correlation ($P < 0.05$) among Sand (%), Silt (%) and Clay (%) in Afroalpine and Dry Evergreen Afromontane regions, because the sum of the percentage of each textural component should be 100. Similarly, EC was strongly positively correlated with TDS both in Dry Evergreen Evergreen Afromontane and Afroalpine regions, because the value of TDS is equal to the sum of 260 and the value of EC.

In Afroalpine vegetation, Altitude had significant negative correlation ($P < 0.05$) with slope because in average the Choke Mountains becomes dome shaped as altitude increases. Disturbance had significant negative correlation ($P < 0.05$) with Silt (%) in Afroalpine vegetation. The percentage of Silt decreased as disturbance increased. Disturbance might facilitate erosion of silt soil since the particle size and weight of the silt is relatively less than Sand particle. Altitude had significant negative correlation ($P < 0.05$) with Silt (%). It could potentially associate with decreasing sloppiness of the mountain as Altitude increase. Slope showed significant negative correlation ($P < 0.05$) with Sand (%). The sand particles may be taken from high sloppy area to less sloppy area due to erosion.

In Dry Evegreen vegetation, Disturbance showed significant negatively correlation ($P < 0.05$) with Altitude since farmlands were closely contacted with grazing lands at the bottom of the the mountain forest. Consequently, disturbance was intensive at the bottom but it relatively decreased with increasing altitude. Slope showed significant positive correlation ($P < 0.05$) with pH. Such relation could be due to the fact that increasing slope results in increased leaching and a reduction in soluble cations, leading to lower H^+ activity and manifested as increased pH levels. TDS and EC had significant negative correlation ($P < 0.05$) with Sand (%), Silt (%) and Clay (%). This might be related with the fact that if Sand (%) increases in a soil texture then the chance of salt solubility increases during sample soil analysis and then it may leach out. Sandy soils tended to be less saline because salts do not attach to sand particles so are easily leached through the soils. Salts tend to attach to clay particles, so clay soils tended to be more saline for longer. Similarly, the correlation of Silt (%) with EC and TDS might associate with chance of solubility of salts in silt soil following sandy soil.

6.7. Structure

A. Density: In general, the five most significant woody species which contributed the highest stem density of the mountain forests were *Maytenus arbutifolia*, *Maesa lanceolata*, *Acacia abyssinica*, *Bersama abyssinica* and *Pittosporum virdiflorum.* In community type 3, *Maytenus arbutifolia* and *Maesa lanceolata* had highest stem density. The vegetation of this community type was moderately disturbed with livestock and selective cuttings. This moderate disturbance might cause to increase the density of *Maytenus arbutifolia* and *Maesa lanceolata*. Similarly, community type1was found to have highest stem density of *Acacia abyssinica* and *Bersama abyssinica*. This community type was located at the peripheral of forests of the Study Mountains, and as a consequence it was subjected to anthropogenic and livestock disturbance. Being largeness of the Acacia tree and non-palatability of *Bersama abyssinica* may cause to increase the density of both species in the community type 1.

Small sized stems of woody species were dominant in community type 3 of Dry Evergreen Afromontane vegetation. This highest density may indicate good regeneration status since the community was secondary forest. The previous forests might destroy by human activities. In 1991(during ‘Derg’ regime) kurub, Chung and Kasakan Mountains were used for strategic sites for military activities. Even now there are few remnant military bankers on Kurub Mountain. Relatively, community type1, 2, 4 and 5 had some large sized woody species which dominant over the small size woody species.

B. Frequency: In general, the five most frequently woody species in the Dry Evergreen Afromontane vegetation were *Maesa lanceolata, Maytenus arbutifolia, Acacia abyssinica, Prunus africana* and *Pittosporum virdiflorum.* These 5 woody species attributed 59.86% of the total relative frequency. Some species such as *Dovyalis abyssinica* and *Ekebergia capensis* exhibited less frequency and they restricted in community types 5 only. A few individuals of *Schefflera abyssinica* exhibited largest canopy and DBH in community type 4. Muller-domboise and Ellenberg (1974) described about frequency that species with a large number of individuals may show low frequency values simply because the individuals are concentrated in patches whereas a species with the same number of individuals spread evenly over the sample area may show 100% frequency. Frequency confounds the two parameters of density and dispersion. A species with a few individuals but large or basal area that considerable portion of the sample area, will give low frequency. Lampricht (1989) pointed out high value in higher frequency and low value in lower frequency classes indicate similar species composition, whereas high value in lower frequency classes and low values in higher frequency indicate high degree of floristic heterogeneity. Based these concepts, the study areas was evaluated weather they were homogeneous or heterogeneous in the woody species composition. In the analysis of frequency for the woody species, high value of frequency percentage was recorded in higher frequency classes, whereas low value of frequency percentage was recorded in lower frequency classes. Thus, these values may indicate the occurrence of similar woody species composition in community type 1, 2 and 3.

C. Basal Area: In general, the basal area increased with increasing DBH classes, but the density and frequency decreased with increasing DBH classes. Larger number of woody individuals concentrated in the lower DBH classes, whereas small number of the woody individuals distributed in the higher DBH classes.

Only three individuals of *Prunus africana*, *Schefflera abyssinica* and *Acacia abyssinica* could achieve to DBH greater than 140 cm. Maximum BA (45.99 m^2/ha) was recorded in community 4 (*Schefflera abyssinica - Myrsine melanophloeos* type).The sample plots of this community types were distributed in Darken and Guble Mountains forests.

Highest DBH and BA values per a few tree individuals in the Darken and Guble Mountain forests may indicate the forests were relatively stable with a composition of big and matured trees. On the other hand, less DBH value per largest number of trees and shrubs individuals in community type 1 and 2 may indicate the communities were composed of small sized-trees. Most of sample plots of these community types were distributed in Kurub, Chung and Kasakan Mountain Forests. From this analysis one may guess that Guble and Darken were relatively stable forests whereas Kurub, Chung and Kasakan were historically disturbed, unstable and they were secondary succession forests.

The normal basal area value for virgin tropical forests in Africa is 23 to 37 m^2/ha (Darwin, 1959 cited in Lamprecht, 1989). Thus, 28.65 m^2/ha was the total basal area of this study, indicating normal value.

D. Storey: In general, the number woody individuals decreased with increasing height classes, depicting positively skewed pattern. The pattern revealed the distribution of large number of individuals in the lowest height class and few individuals in the highest height class. Therefore, the pattern suggests a multi storey vegetation.

E. population structure for selected woody species: Four patterns of species population structure were recognized for selected woody species (Figure 46). The first pattern was the *inverted J-shaped*, represented by *Maytenus arbutifolia,* indicating good reproduction or regeneration dynamics, especially in moderately disturbed areas. The shape may caused by past incidence of disturbance. The second pattern was *Gaussian-shaped*, represented by *Prunus africana,* indicating poor regeneration. It might associate with selective cutting of the big trees and current disturbance of seedlings and saplings. The third pattern was *J-shaped* distribution represented by *Dombeya torrida,* indicating poor regeneration. Feyera Senbeta (2006) suggested that poor regeneration might be caused by either most trees are not producing seeds due to age or there are losses due to predators after reproduction. The forth pattern was *U-shaped*, represented by *Canthium oligocarpum.* This pattern probably indicated selective cutting and removal of medium-sized tree individuals (Tamirat Bekele, 1993). Those woody species which have poor reproduction and recruitment need a proper management.

F. Importance value (IV): Importance value index is considered as the most realistic aspect in vegetation study (Curtis and Mcintosh, 1951) because it is useful to compare the ecological significance of species, in addition, high density and high frequency coupled with high BA indicates the overall dominant species of the forest (Lamprecht, 1989). High Important value of a species in a given community indicates high value of the species with respect to sociological structure (Lamprecht, 1989). With regard to each mountain forest (Appendix 13 and 14), *Maytenus arbutifolia and Maesa lanceolata* exhibited the first and second highest IVI in community type 3.

IV is used for setting priority of ranking species management and conservation practices and help to identify their sociological status in a certain plant community as dominant or rare species (Kent and Coker, 1992). Species such as *Albizia schimperiana, Ekebergia capensis*, *Croton macrostachyus* and *Teclea nobilis* exhibited the least IV, indicating that they need conservation management.

6.8. Regeneration

Normal distribution of seedling, sapling and matured woody species was recorded in community type 1, 2, 3 and 5 because the density/ha of seedlings was greater than the density/ha of saplings and the density/ha of saplings was greater than the density/ha of matured individuals.

This age distribution indicated that the regeneration of the community types was in a good status. Community type 4 did not show normal distribution of density/ha of seedlings saplings and mature individuals. Farm animals might affect the normal age distribution, because many tracks of cattle, goats and sheep were seen while the data was being collected. In addition, the canopy of some big and matured trees might affect the growth of some shade intolerance saplings.

To determine conservation priority, the seedlings of tree and shrub species were categorized into three groups: species having 0 or 1seedlings/ha (group I), species having 1 to 15 seedlings/ha (group II) and Species having greater than 15 seedlings/ha (group III).

Conservation priority has to be given to species under group I and II. Woody species categorized under group I were *Albizia schimperiana, Croton macrostachyus, Ekebergia capensis, Euphorbia amliphylla.* Woody species categorized under group II were *Teclea nobilis, Nuxia congesta, Dovyalis abyssinica, Rosa abyysinica, Galiniera coffeoides* and *Schefflera abyssinica.* According to Simon Shibru and Girma Balcha (2004), these woody species need conservation priority since they exhibited less than 16 seedlings/ha.

6.9. Phytogeographical comparison

Sorenson's similarity index has been applied to quantify the similarity of the floristic composition of the Choke-Koso Ber Mountain range with the floristic composition of other mountains in Ethiopia.

The output of Sorenson's floristic similarity index shows that the vegetation of Simien Mountain exhibited the highest floristic similarity to the vegetation of Choke-Koso Ber mountain range. Relatively, the Simien is the nearest mountain to Choke-Koso Ber

Mountain range and both mountains are located in Southwest of Ethiopian highlands that denote that there are some similarities between the two mountains in ecosystem and floristic composition.

The second highest Sorenson's floristic similarity occurred between the Dry Evergreen Afromontane vegetation of this study and Dodola as well as Menagesha Suba forests. The least Sorenson's floristic similarity index was recorded between the Gurage Mountain and the Choke-Koso Ber Mountain range. All of these are relatively far away from Choke-Koso Ber Mountain range.

6.10. Conclusion and recommendation

The analysis of floristic data confirmed that the Choke-Koso Ber Mountain range hosted high plant diversity and endemic species to Ethiopia.

Altitude, Sand (%), Disturbances, Clay (%), Silt (%) and Slope were important environmental factors which influenced on the distribution of plant species in some community types along the mountains. Those identified plant species in this study mountain range but not recorded in the in Gojjam (GJ) Floristic Region of the Flora of Ethiopia and Eritrea may be used as additional input to improve the GJ Region of the Flora books.

Euryops pinifolius - Alchemilla abyssinica community type covered the largest area of disturbed Afroalpine Vegetation in the Choke Mountain range. If an area of the

Afroalpine vegetation of the mountain range is dominated with *Euryops pinifolius*, it is possible to guess that the vegetation may have been disturbed with intensive grazing. Therefore, *Euryops pinifolius* can serve as an indicator species of disturbed Afroalpine vegetation in the Choke the Mountain range since this unpalatable species is profusely grown in overgrazed lands.

Even though a good regeneration status of most woody species occurred in Dry Evergreen Afromontane vegetation, there is still selective cutting for economically important trees and shrubs. *Albizia schimperiana*, *Ekebergia capensis*, *Teclea nobilis*, *Euphorbia amliphylla*, *Nuxia congesta* and *Schefflera abyssinica* are tree species which need conservation management.

The identified plant species of the mountain range may be used as a key to predict which plant species inhabited the nearby farmlands prior to farming. The findings of this study are also supposed to be important for conservation management and serve as a base line for further studies.

Encroachments, expansion of farmlands (now up to 3800 m elevation in the case of Choke Mountains), grazing, clearings and selective cuttings, firewood collecting, land degradation and erosion are the major threats to the plant diversity and ecosystem of the Choke-Koso Ber Mountain range, and even the threat may cause to the extinction the endemic plant species. In addition, analysis of soil sample of the mountain range indicated that loamy soil was the dominant textural class which needs attention because of its highest erodible property. Thus, the following recommendations are forwarded.

1. Since the Ethiopian Renaissance Dam is being constructed within the watershed of the Choke-Koso Ber Mountain range, there is a risk of siltation at the dam as a result loss of the protective vegetation cover and high erodibility of the soil of the mountain. Thus, community awareness, community based conservation programs, sustainable uses of the remnant natural vegetation, physical and biological land management, implementation of alternative resource of energy and application of sustainable technologies that improve yields in the existing farmland are indispensable. Sustainable mountain management and development is also important for reducing accelerated erosion, modulating runoff regime and contributing sustainable groundwater recharge to lowland areas.

2. Protecting and developing these diversified plants is important to keep the mountain range green, so that it may have a little contribution to the Ethiopia's Climate-Resilient Green Economy strategy.

3. Finally, further research is needed to fill gaps of this research such as analysis of soil seed, the impact of climate change on the distribution of the vegetation (especially for those expected species that may migrate upwards along the mountains in order to survive within their bioclimatic belt), carbon sequestration and medicinal importance of some plant species.

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Appendices

Appendix1. List of plant species recorded from the vegetation of Choke-Koso Ber Mountain range (Choke, Kurub, Chung, Kasakan, Guble and Darken Mountains)

S. No.	**Scientific name**	**Family**	**Habit**
1	*Abildgaardia boeckeleriana* (Schweinf.) A.A. Beetle	Cyperaceae	Herb
2	*Acacia abyssinica* Hochst. ex Benth.	Fabaceae	Tree
3	*Achyranthes aspera* L.	Amarantaceae	Herb
4	*Achyrospermum schimperi* (Hochst. ex Briq.) Perkins	Lamiaceae	Herb
5	*Adiantum poiretii* Wikstr	Adiantaceae	Herb
6	*Agrocharis melanantha* Hochst.	Apiaceae	Herb
7	*Aira caryophyllea* L.	Poaceae	Herb
8	*Albizia schimperiana* Oliv.	Fabaceae	Tree
9	*Alchemilla abyssinica* Fresen.	Rosaceae	Herb
10	*Alchemilla microbetula* Th. C.E. Fries	Rosaceae	Herb
11	*Allophylus abyssincus* (Hochst.) Radlk.	Sapindaceae	Tree
12	*Amphicarpa africana* (Hook. f.) Harms	Fabaceae	Climber herb
13	*Anarrhinum forkaohlii* (Gmel.) Cufod., subsp. *abyssinicum* (Jaub. & Spaeh) D.A. Sutton	Scrophulariaceae	Shrub
14	*Andropagon abyssinicus* Fresen.	Poaceae	Herb
15	*Andropagon* sp.	Poaceae	Herb
16	*Andropogon distachyos* L.	Poaceae	Herb
17	*Andropogon lima* (Hack.) Stapf.	Poaceae	Herb
18	*Anthemis tigreensis* J. Gay ex A. Rich.	Asteraceae	Herb
19	*Arabis alpina* L.	Brassicaceae	Herb
20	*Arundinaria alpina* K. Schum.	Poaceae	Shrub
21	*Arundo donax* L.	Poaceae	Shrub
22	*Asparagus africanus* Lam.	Asparagaceae	Shrub
23	*Asplenium aethopicum* (Burm. f.) Bech.	Aspleniaceae	Herb
24	*Asplenium theciferum* (Humb. Bonple. & Kunth) Mett.	Aspleniaceae	Herb
25	*Bartsia longiflora* Hochst.ex Benth.	Scrophulariaceae	Shrub
26	*Bersama abyssinica* Fresen.	Melianthaceae	Shrub/Tree
27	*Bidens macroptera* (Sch. Bip. ex Chiov.) Mesfin	Asteraceae	Herb
28	*Bidens pachyloma* (Olive. & Hiern.) Cufod.	Asteraceae	Herb

S. No.	Scientific name	Family	Habit
29	*Bidens prestinaria* (Sch.-Bip.) Cufod.	Asteraceae	Herb
30	*Blechnum attenuatum* (Sw.) Mett.	Blechanaceae	Herb
31	*Bothriocline schimperi* Oliv. & Hiern ex Benth.	Asteraceae	Shrub
32	*Brachymenium* sp.	Bryaceae	Moss (Herb)
33	*Brucea antidysenterica* J.F. Mill.	Simaroubaceae	Shrub
34	*Buddlja polystachya* Fresen.	Loganiaceae	Shrub/Tree
35	*Canarina abyssinica* Engl.	Capanulaceae	Herb
36	*Canthium oligocarpum* Hiern.	Rubiaceae	Shrub
37	*Cardamine africana* L.	Brassicaceae	Herb
38	*Cardamine trichocarpa* A. Rich.	Brassicaceae	Herb
39	*Carduus schimperi* Sch. Bip. ex A. Rich. Type Carduus ellenbeckii R.F. Fries	Asteraceae	Herb
40	*Carex erythrorrhiza* Bock.	Cyperaceae	Herb
41	*Caucalis melanantha* (Hochst.) Hiern	Apiaceae	Herb
42	*Cerastium octandrum* Hochst. ex A. Rich.	Caryophyllaceae	Herb
43	*Cerastium afromontanum* Th. Fr. Jr. & Weimarck	Caryophylaceae	Herb
44	*Cheilanthes farinosa* (Forssk.) Kaulf.	Spinopteridaceae	Herb
45	*Cineraria deltoiden* Sond.	Asteraceae	Herb
46	*Cineraria sebaldii* Cufod.	Asteraceae	Herb
47	*Cirsium vulgare* (Savi.) Ten.	Asteraceae	Herb
48	*Clausena anisata* (Willd.) Benth.	Rutaceae	Shrub
49	*Clematis hirsuta* Perr. & Guill	Ranunculaceae	Woody Climber
50	*Clematis simensis* Fresen.	Ranunculaceae	Woody Climber
51	*Clutia lanceolata* Forssk.	Euphorbiaceae	Shrub
52	*Commelina africana* L.	Commelinaceae	Herb
53	*Conyza vernonioides* (Sch. Bip. ex A. Rich.) Willd.	Asteraceae	Herb
54	*Conyza rubricaulis* R.E. Fries	Asteraceae	Herb
55	*Conyza tigrensis* Oliv. & Hiern	Asteraceae	Herb
56	*Cardamine hirsuta* L.	Brassicaceae	Herb
57	*Cotula abyssinica* Sch. Bip. ex A. Rich.	Asteraceae	Herb
58	*Cotula cryptocephala* Sch. Bip. ex A. Rich.	Asteraceae	Herb
59	*Crassula alata* (Viv.) Berger	Crassulaceae	Herb
60	*Crassula schimperi* Fisch. & Mey.	Crassulaceae	Herb
61	*Crepis rueppellii* Sch. Bip.	Asteraceae	Herb
62	*Croton macrostachyus* Del.	Euphorbiaceae	Shrub
63	*Cuscuta campestis* Yuncker	Cuscutaceae	Herb

S. No.	**Scientific name**	**Family**	**Habit**
64	*Cyanoglossum amplifolium* Hochst.	Boraginaceae	Herb
65	*Cyanotis barbata* D. Don.	Commelinaceae	Herb
66	*Cyanotis polyrrhiza* Hochst. ex Hassk.	Commelinaceae	Herb
67	*Cynodon dactylon* (L.) Pers.	Poaceae	Herb
68	*Cynoglossum coeruleum* Hochst. ex A.DC. in DC. subsp. geometricum (Bak. & Wright) Edwards	Boraginaceae	Herb
69	*Cyperus fischerianus* A. Rich.	Cyperaceae	Herb
70	*Cyperus* sp.	Cyperaceae	Herb
71	*Davallia denticulata* (Burm. f) mett. ex Kuhn var. *denticulata*	Davalliaceae	Herb
72	*Deschampsia caespitosa* (L.) P. Beauv.	Poaceae	Herb
73	*Dianthoseris schimperi* Sch. Bip ex A. Rich.	Asteraceae	Herb
74	*Diaphananthe schipmeriana* (A. Rich.) Summerh.	Orchidaceae	Herb
75	*Dicrocephala chrysanthemifolia* (Bl.) Dc.	Asteraceae	Herb
76	*Digitaria ternata* (A. Rich.) Stapf.	Poaceae	Herb
77	*Discopodium penninervium* Hochst.	Solanaceae	Shrub
78	*Dombeya torrida* (J.F. Gmel.) P. Bamps	Sterculaceae	Tree
79	*Dovyalis abyssinica* (A. Rich.) Warb.	Flacortiaceae	Tree
80	*Drymarya cordata* (L.) Wild. ex Roem. et schult.	Caryophyllaceae	Herb
81	*Drynaria volkensii* Hieron	Polypodiaceae	Herb
82	*Dyschoriste radicans* Nees	Acanthaceae	Herb
83	*Echinops longisetus* A. Rich.	Asteraceae	Shrub
84	*Ekebergia capensis* Spamn.	Meliaceae	Tree
85	*Elatostema monticolum* Hook.f.	Urticaceae	Herb
86	*Embelia schimperi* Vatake	Myrsinaceae	Woody Climber
87	*Epilobium stereophyllum* Fresen.	Onagraceae	Herb
88	*Eragrostis cilianensis* (All.) Vign.ex Janchen.	Poaceae	Herb
89	*Eragrostis papposa* (Roem. & Schult.) Steud.	Poaceae	Herb
90	*Erica arborea* L.	Ericaceae	Shrub
91	*Erodium moschatum* (L.) ex Aiton.	Geraniaceae	Herb
92	*Erucastrum arabicum* Fisch. & May.	Brassicaceae	Herb
93	*Erythrina brucei* Schweinf.	Fabaceae	Tree
94	*Euphorbia amliphylla* Pax.	Euphorbiaceae	Tree
95	*Euphorbia schimperiana* Scheele	Euphorbiaceae	Herb
96	*Euryops pinifolius* A. Rich.	Asteraceae	Shrub
97	*Festuca abyssinica* Hochst. ex A.Rich.	Poaceae	Herb
98	*Festuca macrophylla* Hochst. ex A. Rich.	Poaceae	Herb

S. No.	**Scientific name**	**Family**	**Habit**
99	*Festuca simensis* Hochst. ex A. Rich.	Poaceae	Herb
100	*Galiniera coffeoides* Del.	Rubiaceae	Shrub
101	*Galinsoga parviflora* Cav.	Asteraceae	Herb
102	*Galium aparinoides* Forssk.	Rubiaceae	Herb
103	*Geranium aculeolatum* Olivo	Gereniaceae	Herb
104	*Geranium arabicum* Forssk.	Gereniaceae	Herb
105	*Girardinia bullosa* (Steud.) Wedd.	Urticaceae	Herb
106	*Glycine wightii* (Wight & Arn.) Vardc.	Fabaceae	Climber herb
107	*Gnaphalium rubriflorum* Hilliard	Asteraceae	Herb
108	*Gnaphalum tweedieae*Hilliard	Asteraceae	Herb
109	*Gnidia glauca* (Fresen.) Gilg.	Thymelaeaceae	Tree
110	*Habenaria* sp.	Orchidaceae	Herb
111	*Habenaria vaginata* A. Rich.	Orchidaceae	Herb
112	*Hagenia abyssinica* (Bruce) J.F.Gmel.	Rosaceae	Tree
113	*Haplocarpha rueppellii* (Sch. Bip.) Beauv.	Asteraceae	Herb
114	*Haplocarpha schimperi* (Sch. Bip.) Beauv.	Asteraceae	Herb
115	*Hedwigia ciliata* (Hedw.) P. Beauv.	Hedwigiaceae	Moss (Herb)
116	*Helichrysum schimperi* (Sch. Bip. ex A. Rich.) Moser	Asteraceae	Shrub
117	*Helichrysum citrispinum* Del.	Asteraceae	Shrub
118	*Helichrysum foetidum* (L.) Monch.	Asteraceae	Herb
119	*Helichrysum formosissimum* Sch.Bip ex A. Rich.	Asteraceae	Herb
120	*Helictotrichon elongatum* (Hochst. ex A. Rich.) C.E. Hubbard	Poaceae	Herb
121	*Heracleum abyssinicum* (Boiss.) Norman	Apiaceae	Herb
122	*Hydrocotyle mannii* Hook. F.	Apiaceae	Herb
123	*Hydrocotyle sibthorpioides* Lam.	Apiaceae	Herb
124	*Hypericum quartinianum* A. Rich.	Hypericaceae	Shrub
125	*Hypericum revolutum* Vahl	Hypericaceae	Shrub
126	*Hypoestes forskaolii* (Vahl) R. Br.	Acanthaceae	Herb
127	*Hypoestes triflora* (Forssk.) Roem & Schult.	Acanthaceae	Herb
128	*Hypolepis goetzei* Hieron ex Reimers	Dennstaedtiaceae	Herb
129	*Impatiens ethiopica* Grey-Wilson	Balsaminaceae	Herb
130	*Impatiens hochstetteri* Warb.	Balsaminaceae	Herb
131	*Isolepis fluitans* (L.) R. Br.	Cyperaceae	Herb
132	*Justicia diclipteroides* Lindau	Acanthaceae	Herb
133	*Justicia schimperiana* (Hochst. ex Nees) T. Anders.	Acanthaceae	Shrub
134	*Kalanchoe petitiana* A. Rich. var. *neumannii* (Engl.) Cuf.	Crassulaceae	Herb

S. No.	Scientific name	Family	Habit
135	*Kalanchoe schimperiana* A. Rich.	Crassulaceae	Subshrub
136	*Kniphofia foliosa* Hochst.	Asphodelaceae	Herb
137	*Kniphofia insignis* Rendle	Asphodelaceae	Herb
138	*Kniphofia pumila* (Ait.) Kunth	Asphodelaceae	Herb
139	*Koeleria pyramidata* (Lam.) Domin	Poaceae	Herb
140	*Lactuca inermis* Forssk.	Asteraceae	Herb
141	*Launaea rueppellii (*Sch. Bip. ex Olive. & Hiern) L.	Asteraceae	Herb
142	*Leonotis ocymifolia* (Burm. f.) Iwarsson var. *raineriana* (Vis.) Iwarsson	Lamiaceae	Shrub
143	*Lobelia erlangeriana* Engl.	Lobeliaceae	Herb
144	*Lobelia rhyncopetalum* (Hochst) Hemsl.	Lobeliaceae	Herb
145	*Maesa lanceolata* Forssk.	Myrsinaceae	Tree
146	*Malva verticillata* L.	Malvaceae	Herb
147	*Maytenus arbutifolia* (Hochst. ex A. Rich.) Wilczek var. arbutifolia	Celastraceae	Shrub/tree
148	*Maytenus gracilipes* (Welw. ex Oliv.) Excell sub sp. arguta (Loes.) Sebsebe	Celastraceae	Herb
149	*Medicago polymorpha* L.	Fabaceae	Herb
150	*Merendera abyssinica* A. Rich.	Colchicaceae	Herb
151	*Merendera schimperiana* Hochst.	Colchicaceae	Herb
152	*Mikaniopsis clematoides* (A. Rich.) Milne-Redh.	Asteraceae	Woody Climber
153	*Minuartia filifolia* (Forssk.) Mattf.	Caryophylaceae	Shrub
154	*Momordica foetida* Schumach	Cucurbitaceae	Climber herb
155	*Myrsine melanophloeos* (L.) R. Br.	Myrsinaceae	Tree
156	*Neckera platyantha* (C. Mull.) Pan.	Neckeraceae	Moss (herb)
157	*Nuxia congesta* K.Br. ex Fresen.	Loganiaceae	Tree
158	*Orobanche ramosa* L.	Orobanchaceae	Herb
159	*Oxalis procumbens* Steud. ex. A Rich.	Oxalidaceae	Herb
160	*Parietaria debilis* G. Forst.	Urticaceae	Herb
161	*Pavonia urens* Cav.	Malvaceae	Shrub
162	*Pennisetum humile* Hochst ex A. Rich	Poaceae	Herb
163	*Pennisetum sphacelatum* (Nees) Th. Dur. & Schinz	Poaceae	Herb
164	*Pennisetum thunbergii* Kunth	Poaceae	Herb
165	*Pennisetum*sp.	Poaceae	Herb
166	*Peperomia abyssinica* Miq.	Piperaceae	Herb
167	*Peucedanum petitianum* A. Rich.	Apiaceae	Herb
168	*Phagnalon abyssinicum* Sch. Bip. ex A. Rich.	Asteraceae	Herb

S. No.	**Scientific name**	**Family**	**Habit**
169	*Phragmanthera regularis* (Sparague) M. Gilbert	Loranthaceae	Woody Climber
170	*Phytolacca dodecandra* L'Herit.	Phytolacacceae	Shrub
171	*Pittosporum virdiflorum* Sims.	Pittosporaceae	Tree
172	*Plantago afra* L. var. *stricta* (Schousb.)Verdc.	Plantaginaceae	Herb
173	*Plantago lanceolata* L.	Plantaginaceae	Herb
174	*Plantago palmata* Hook.f.	Plantaginaceae	Herb
175	*Plectranthus glandulosus* Hook. f.	Lamiaceae	Herb
176	*Pleopeltis macrocarpa* (Willd.) Kaulf	Polypodiaceae	Herb
177	*Poa annua* L.	Poaceae	Herb
178	*Poa chokensis* S.M Phillips	Poaceae	Herb
179	*Poa hedbergii* S.M. Phillips	Poaceae	Herb
180	*Poa leptoclada* Hochst. ex A. Rich.	Poaceae	Herb
181	*Poa schimperiana* Hochst. ex A. Rich.	Poaceae	Herb
182	*Polycarpon tetraphyllum* (L.) L.	Caryophylaceae	Herb
183	*Polystachya eurychila* Summerh.	Orchidaceae	Herb
184	*Prunus africana* (Hook. f.) kalkm.	Rosaceae	Tree
185	*Pseudognaphalium oligandrum* (DC.) Hilliard & Brutt.	Asteraceae	Herb
186	*Pseudognaphalium richardianum* (Cufod.) Hilliard & Burtt.	Asteraceae	Herb
187	*Pteridium aquilinum* (L.) Kuhn	Hypolepidaceae	Herb
188	*Pteris catoptera* Kunze	Pteridaceae	Herb
189	*Ranunculus oreophytus* Del.	Ranunculaceae	Herb
190	*Rhabdotosperma scrofulariifolia* (Hochst.ex A. Rich.)Hartl.	Scrophulariaceae	Herb
191	*Rosa abyssinica* Lindley	Rosaceae	Shrub
192	*Rubia cordifolia* L.	Rubiaceae	Herb
193	*Rubus steudneri* Schweinf.	Rosaceae	Woody Climber
194	*Rumex abyssinicus* Jacq.	Polygonaceae	Herb
195	*Rumex nepalensis* Spreng.	Polygonaceae	Herb
196	*Rumex nervosus* Vahl	Polygonaceae	Shrub
197	*Sagina abyssinica* Hochst. ex A. Rich.	Caryophyllaceae	Herb
198	*Salvia merjamie* Forssk.	Lamiaceae	Herb
199	*Salvia nilotica* Jacq.	Lamiaceae	Herb
200	*Sanicula elta* Buch.-Ham. ex Don	Apiaceae	Herb
201	*Satureja paradoxa* (Vatake) Engl. ex Seybold	Lamiaceae	Herb
202	*Satureja punctata* (Benth.) Briq.	Lamiaceae	Shrub
203	*Satureja biflora* (Ham. ex Don) Briq.	Lamiaceae	Subshrub

S. No.	Scientific name	Family	Habit
204	*Satureja pseudosimensis* Bernan	Lamiaceae	Herb
205	*Saxifraga hederifolia* Hochst ex. A. Rich.	Saxifragaceae	Herb
206	*Scadoxus multiflorus* (Martyn) Raf. subsp. *multiflorus*	Amaryllidacea	Herb
207	*Schefflera abyssinica* (Hochst. ex A. Rich.) Harms	Araliaceae	Tree
208	*Schoenoplectus corymbosus* (Roem & Schult.) Rayn.	Cyperaceae	Herb
209	*Sedum mooneyi* M. Gilbert	Crassulaceae	Herb
210	*Selaginella abyssinica* Spring	Selaginellaceae	Herb
211	*Silene burchellii* Dc.	Caryophyllaceae	Herb
212	*Sium simense* Gay. ex A. Rich.	Apiaceae	Herb
213	*Solanecio gigas* (Vatke) C. Jeffrey	Asteraceae	Shrub
214	*Solanum benderianum* Schimper ex Dammer	Solonaceae	Woody Climber
215	*Solanum incanum*L.	Solanaceae	Shrub
216	*Solanum indicum* L.	Solanaceae	Shrub
217	*Solanum marignatum* L.f	Solonaceae	Shrub
218	*Solenostemon autrani* (Briq.) J.K. Morton	Lamiaceae	Herb
219	*Spergularia* sp.	Caryophyllaceae	Herb
220	*Sporobolus africanus* (Poir.) Robyns & Tournay	Poaceae	Herb
221	*Stephania abyssinica* (Dillon. & A. Rich.) Walp.	Menispermaceae	Climber herb
222	*Subularia monticola* Schweinf.	Brassicaceae	Herb
223	*Swertia abyssinica* Hochst.	Gentianaceae	Herb
224	*Swertia lugardae* Bullock	Gentianaceae	Herb
225	*Teclea nobilis* Del.	Rutaceae	Tree
226	*Thalictrum schimperianum* Hochst. ex Schweinf.	Ranunculaceae	Herb
227	*Thymus schimperi Ronniger*	Lamiaceae	Herb
228	*Trifolium acaule* Steud. ex A. Rich.	Fabaceae	Herb
229	*Trifolium bilineatum* Fresen.	Fabaceae	Herb
230	*Trifolium Cryptopodium* Steud. ex A. Rich.	Fabaceae	Herb
231	*Trifolium decorum* Chiov.	Fabaceae	Herb
232	*Trifolium rueppellianum* Fresen.	Fabaceae	Herb
233	*Trifolium simense* Fresen.	Fabaceae	Herb
234	*Trifolium steudneri* Schweinf.	Fabaceae	Herb
235	*Umbilicus botryoides* Hochst. ex A. Rich.	Crassulaceae	Herb
236	*Urera hypselodendron* (Hochst ex A. Rich). Wedd.	Urticaceae	Woody Climber
237	*Ursinia nana* DC.	Asteraceae	Herb
238	*Urtica simensis* Steudel.	Urticaceae	Herb

S. No.	Scientific name	Family	Habit
239	*Verbascum sinaiticum* Benth.	Scrophulariaceae	Herb
240	*Vernonia auriculifera* Hiern	Asteraceae	Shrub
241	*Vernonia bipontini* Vatake	Asteraceae	Shrub
242	*Vernonia myriantha* Hook. f.	Asteraceae	Shrub
243	*Vulpia bromoides* (L.) S.F. Gray	Poaceae	Herb

Appendix 2. List of endemic plant species recorded from the vegetation of Choke -Koso Ber Mountain range

S. No.	Scientific name	Family	Habit
1	*Anarrhinus forkaohlii* (Gmel.) Cufod., subsp. *abyssinicum* (Jaub. & Spaeh) D.A. Sutton	Scrophulariaceae	Shrub
2	*Bidens macroptera* (Sch. Bip. ex Chiov.) Mesfin	Asteraceae	Herb
3	*Bidens pachyloma* (Olive. & Hiern.) Cufod.	Asteraceae	Herb
4	*Bothriocline schimperi* Oliv. & Hiern ex Benth.	Asteraceae	Shrub
5	*Cineraria sebaldii* Cufod.	Asteraceae	Herb
6	*Cyanotis polyrrhiza* Hochst. ex Hassk.	Commelinaceae	Herb
7	*Echinops longisetus* A. Rich.	Asteraceae	Shrub
8	*Erythrina brucei* Schweinf.	Fabaceae	Tree
9	*Euryops pinifolius* A. Rich.	Asteraceae	Herb
10	*Festuca macrophylla* Hochst. ex A. Rich.	Poaceae	Herb
11	*Justiacea diclipteroides* Lindau	Acanthaceae	Herb
12	*Kalanchoe petitiana*A. Rich. Var. *neumannii* (Engl.) Cuf.	Crassulaceae	Herb
13	*Kalanchoe schimperiana* A. Rich.	Crassulaceae	Subshrub
14	*Kniphofia foliosa* Hochst.	Asphodelaceae	Herb
15	*Kniphofia insignis* Rendle	Asphodelaceae	Herb
16	*Launaea rueppellii (*Sch. Bip. ex Olive. & Hiern) L.	Asteraceae	Herb
17	*Lobelia erlangeriana* Engl.	Lobeliaceae	Herb

S. No.	Scientific name	Family	Habit
18	*Lobelia rhyncopetalum* (Hochst) Hemsl.	Lobeliaceae	Herb
19	*Mikaniopsis clematoides* (A. Rich.) Milne-Redh.	Asteraceae	Woody Climber
20	*Peucedanum petitianum* A. Rich.	Apiaceae	Herb
21	*Poa chokensis* S.M Phillips	Poaceae	Herb
22	*Poa hedbergii* S.M. Phillips	Poaceae	Herb
23	*Polycarpon tetraphyllum* (L.) L.	Caryophylaceae	Herb
24	*Sagina abyssinica* Hochst. ex A. Rich.	Caryophyllaceae	Herb
25	*Satureja paradoxa* (Vatake) Engl. ex Seybold	Lamiaceae	Herb
26	*Saxifraga hederifolia* Hochst ex. A. Rich.	Saxifragaceae	Herb
27	*Sedum mooneyi* M. Gilbert	Crassulaceae	Herb
28	*Solanecio gigas* (Vatke) C. Jeffrey	Asteraceae	Shrub
29	*Thalictrum schipmerianum* Hochst. ex Schweinf.	Ranunculaceae	Herb
30	*Thymus schimperi Ronniger*	Lamiaceae	Herb
31	*Trifolium bilineatum* Fresen.	Fabaceae	Herb
32	*Trifolium decorum* Chiov.	Fabaceae	Herb
33	*Urtica simensis* Steudel.	Urticaceae	Herb

Appendix 3. List of plant species recorded from the vegetation of Choke-Koso Ber Mountain range, but not reported in the Gojjam (GJ) Floristic Region of the Flora of Ethiopia and Eritrea

S. No.	Scientific name	Family	Habit
1	*Abildgaardia boeckeleriana* (Schweinf.) A.A. Beetle	Cyperaceae	Herb
2	*Amphicarpa africana* (Hook. f.) Harms	Fabaceae	Climber
3	*Anarrhinus forkaohlii* (Gmel.) Cufod., subsp. *abyssinicum* (Jaub. & Spaeh) D.A. Sutton	Scrophulariaceae	Shrub
4	*Andropogon lima* (Hack.) Stapf.	Poaceae	Herb
5	*Asparagus africanus* L.	Asparagaceae	Shrub
6	*Blechnum attenuatum* (Sw.) Mett.	Blechanaceae	Herb
7	*Cerastium afromontanum* Th. Fr. Jr. & Weimarck	Caryophylaceae	Herb
8	*Cineraria sebaldii* Cufod.	Asteraceae	Herb
9	*Clutia lanceolata* Forssk.	Euphorbiaceae	Shrub
10	*Commelina africana* L.	Commelinaceae	Herb
11	*Cotula cryptocephala* Sch. Bip. ex A. Rich.	Asteraceae	Herb

S. No.	Scientific name	Family	Habit
12	*Cyanotis barbata* D. Don.	Commelinaceae	Herb
13	*Davallia denticulata* (Burm. f) mett. ex Kuhn	Davalliaceae	Herb
14	*Festuca macrophylla* Hochst. ex A. Rich.	Poaceae	Herb
15	*Galiniera coffeoides* Del.	Rubiaceae	Shrub
16	*Galium aparinoides* Forssk.	Rubiaceae	Herb
17	*Habenaria vaginata* A. Rich.	Orchidacea	Herb
18	*Helichrysum foetidum* (L.) Monch.	Asteraceae	Herb
19	*Hydrocotyle sibthorpioides* Lam.	Apiaceae	Herb
20	*Hypolepis goetzei* Hieron ex Reimers	Dennstaedtiaceae	Herb
21	*Impatiens ethiopica* Grey-Wilson	Balsaminaceae	Herb
22	*Justiacea diclipteroides* Lindau	Acanthaceae	Herb
23	*Kalanchoe petitiana*A. Rich. Var. *neumanii* (Engl.) Cuf.	Crassulaceae	Herb
24	*Kalanchoe schimperiana* A. Rich.	Crassulaceae	Subshrub
25	*Kniphofia insignis* Rendle	Asphodelaceae	Herb
26	*Lobelia erlangeriana* Engl.	Lobeliaceae	Herb
27	*Mikaniopsis clematoides* (A. Rich.) Milne-Redh.	Asteraceae	Climber
28	*Pennisetum sphacelatum* (Nees) Th. Dur. & Schinz	Poaceae	Herb
29	*Plectranthus glandulosus* Hook. f.	Lamiaceae	Herb
30	*Poa hedbergii* S.M. Phillips	Poaceae	Herb
31	*Polycarpon tetraphyllum* (L.) L.	Caryophylaceae	Herb
32	*Polystachya eurychila* Summerh.	Orchidaceae	Herb
33	*Pseudognaphalium richardianum* (Cufod.) Hilliard & Burtt.	Asteraceae	Herb
34	*Pteridium aquilinum* (L.) Kuhn	Hypolepidaceae	Herb
35	*Pteris catoptera* Kunze	Pteridaceae	Herb
36	*Scadoxus multiflorus* (Martyn) Raf. subsp. *multiflorus*	Amaryllidacea	Herb
37	*Schefflera abyssinica* (Hochst. ex A. Rich.) Harms	Araliaceae	Tree
38	*Selaginella abyssinica* Spring	Selaginellaceae	Herb
39	*Silene burchellii* Dc.	Caryophyllaceae	Herb
40	*Sium simense* Gay. ex A. Rich.	Apiaceae	Herb
41	*Solanum indicum* L.	Solanaceae	Shrub
42	*Solanum indicum* L.	Solanaceae	Shrub
43	*Solanum marignatum* L.f	Solonaceae	Shrub
44	*Swertia lugardae* Bullock	Gentianaceae	Herb
45	*Thalictrum schipmerianum* Hochst. ex Schweinf.	Ranunculaceae	Herb
46	*Thymus schimperi Ronniger*	Lamiaceae	Herb
47	*Trifolium rueppellianum* Fresen.	Fabaceae	Herb

Appendix 4. Percent of textural classes in community types of Afroalpine vegetation ('C' represents community type)

Txtural class	**C_1**	**C_2**	**C_3**
Loam	7.41	0	11.11
Clay loam	0	0	0
Sandy loam	66.67	71.43	81.48
Sandy clay loam	11.11	22.86	7.41
Loamy sand	14.82	5.71	0

Appendix 5. Range and average of pH, EC and TDS of of soil samples in community types of Afroalpine vegetation
('C' represents community type)

	C_1		**C_2**		**C_3**	
	Range	**Average**	**Range**	**Average**	**Range**	**Average**
pH	4.84 - 5.98	5.33	4.89 - 6.33	5.42	5.14 - 6.34	5.44
EC (mS/cm)	0.04 - 0.23	0.08	0.04 - 0.24	0.09	0.03 - 0.24	0.11
TDS (ppm)	18.41-146.69	48.48	23.64-146.69	54.89	14.4 -146.7	64.66

Appendix 6. Percent of textural classes in community types of Dry Evergreen Afromontane vegetation ('C' represents community type)

Txtural class	**C_1**	**C_2**	**C_3**	**C_4**	**C_5**
Loam	65	17.86	12.5	4	5.56
Clay loam	10	3.57	0	12	0
Sandy loam	15	32.14	62.5	72	77.78
Sandy clay loam	10	42.86	25	4	0
Loamy sand	0	3.57	0	8	16.67

Appendix 7. Range and average of pH, EC and TDS of soil samples in community types of Dry Evergreen Afromontane vegetation

('C' represents community type)

	C_1		**C_2**		**C_3**	
	Range	Average	Range	Average	Range	Average
pH	5.68 - 6.45	6.07	5.66-6.40	6.01	5.79 - 6.48	6.13
EC (mS/cm)	0.014 - 0.12	0.05	0.03 - 0.15	0.06	0.02 - 0.17	0.06
TDS (ppm)	8.67 - 64.73	29.58	13.59-97.90	35.16	8.68-106.3	36.94

	C_4		**C_5**	
	Range	Average	Range	Average
pH	6.0 - 6.50	6.14	5.78 - 6.22	6.01
EC (mS/cm)	0.024 - 0.17	0.08	0.016 - 0.17	0.08
TDS (ppm)	9.99 -106.32	46.68	10.0 - 106.32	50.45

Appendix 8. Summary of ANOVA for environmental variables and plant community types belonging to the Dry Evergreen Afromontane vegetation (Kurub, Chung, Kasakan, Guble and Darken Mountains)

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05

Treatment	Source of variation	DF	SS	MS	F	P
Altitude	Between groups	4	146914	36729	18.10	0.000 ***
	Within groups	118	239508	2030		
	Total	122	386422			
Aspect	Between groups	4	11.83	2.96	2.05	0.092
	Within groups	118	170.20	1.44		
	Total	122	182.03			
Slope	Between groups	4	529	132	0.67	0.614
	Within groups	118	23325	198		
	Total	122	23824			
Sand (%)	Between groups	4	6773	1693	15.37	0.000 ***
	Within groups	118	12997	110		
	Total	122	19770			
Silt (%)	Between groups	4	2834.8	708.7	10.67	0.000 ***
	Within groups	118	7840.4	66.4		
	Total	122	10675.3			
Clay (%)	Between groups	4	1038.3	259.6	4.75	0.001 **
	Within groups	118	6447.2	54.6		
	Total	122	7485.5			
pH	Between groups	4	0.4150	0.1038	3.16	0.017 *
	Within groups	118	3.8803	0.0329		
	Total	122	4.2953			
EC (mS/cm)	Between groups	4	0.01500	0.00375	2.93	0.024 *
	Within groups	118	0.15079	0.00128		
	Total	122	0.16579			
TDS (ppm)	Between groups	4	6148	1537	2.92	0.024 *
	Within groups	118	62085	526		
	Total	122	68234			
Disturbance	Between groups	4	4.969	1.242	2.95	0.023 *
	Within groups	118	49.763	0.422		
	Total	122	54.732			

Appendix 9. Summary of ANOVA for environmental variables and the community types belonging to Afroalpine vegetation (Choke Mountains)

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05

Treatment	Source of variation	DF	SS	MS	F	P
Altitude	Between groups	2	791803	395902	17.32	0.000 ***
	Within groups	86	1966286	22864		
	Total	88	22864			
Aspect	Between groups	2	0.019	0.010	0.02	0.981
	Within groups	86	43.058	0.501		
	Total	88	43.078			
Slope	Between groups	2	397.8	198.9	2.78	0.067
	Within groups	86	6143.2	71.4		
	Total	88	6541.1			
Sand (%)	Between groups	2	89.0	44.5	0.79	0.456
	Within groups	86	4827.4	56.1		
	Total	88	4926.4			
Silt (%)	Between groups	2	889.2	444.6	8.38	0.000 ***
	Within groups	86	4564.0	53.1		
	Total	88	5453.2			
Clay (%)	Between groups	2	425.1	212.6	5.44	0.006 **
	Within groups	86	3358.1	39.0		
	Total	88	3783.2			
pH	Between groups	2	0.2069	0.1034	1.35	0.266
	Within groups	86	6.6050	0.0768		
	Total	88	6.8118			
EC (mS/cm)	Between groups	2	0.00887	0.00444	2.01	0.141
	Within groups	86	0.19024	0.00221		
	Total	88	0.19911			
TDS (ppm)	Between groups	2	140.9	70.5	2.25	0.112
	Within groups	86	2696.2	31.4		
	Total	88	2837.2			
Disturbance	Between groups	2	41.901	20.950	0.424	0.000 ***
	Within groups	86	36.459	0.424		
	Total	88	78.360			

Appendix 10. Density/ha of woody species in community types of the Dry Evergreen Afromontane forest

	Density/ha of stems in community types				
Woody species	**C 1**	**C 2**	**C 3**	**C 4**	**C 5**
Acacia abyssinica	173.75	23.2	5.47	0	3.5714
Albizia schimperiana	0	0	0.78	2	0
Allophylus abyssincus	2.5	3.57	2.34	0	26.786
Bersama abyssinica	111.25	6.25	1.56	0	0
Buddleja polystachya	0	0	30.5	10	12.5
Canthium oligocarpum	0	0	0	5	62.5
Croton macrostachyus	0	0	0	3	8.9286
Dombeya torrida	12.5	21.4	0	9	0
Dovyalis abyssinica	0	0	0	0	19.643
Ekebergia capensis	0	0	0	0	5.3571
Erythrina brucei	2.5	0	0	0	0
Euphorbia amliphylla	0	0	2.34	2	0
Gnidia glauca	0	5.36	33.6	0	0
Maesa lanceolata	0	72.3	231	32	78.571
Maytenus arbutifolia	10	79.5	253	82	14.286
Myrsine melanophloeos	0	5.36	9.38	15	0
Nuxia congesta	0	36.6	5.47	7	14.286
Pittosporum virdiflorum	0	37.5	3.13	20	12.5
Prunus africana	0	1.79	4.69	37	39.286
Schefflera abyssinica	0	0	1.56	22	3.5714
Teclea nobilis	0	0	0	0	7.1429
Rosa abyysinica	0	0	1.56	0	0
Hypericum revolutum	0	0	1.56	0	3.5714
Galiniera coffeoides	0	0.89	2.34	1	1.7857
Total	**300**	**295**	**594**	**258**	**316.07**

Appendix 11. Frequency of woody species of the community types of the Dry Evergreen Afromontane vegetation

	Frequency in community types				
Woody species	**C 1**	**C 2**	**C 3**	**C 4**	**C 5**
Acacia abyssinica	1.05	0.71	0.06	0	0.125
Albizia schimperiana	0	0	0.03	0.08	0
Allophylus abyssincus	0.15	0.04	0.03	0	0.5
Bersama abyssinica	0.35	0.07	0.25	0	0
Buddleja polystachya	0	0	0.28	0.32	0.125
Canthium oligocarpum	0	0	0	0.16	0.75
Croton macrostachyus	0	0	0	0.04	0.125
Dombeya torrida	0.05	0.75	0.13	0.16	0
Dovyalis abyssinica	0	0	0	0	0.313
Ekebergia capensis	0	0	0	0	0.188
Erythrina brucei	0.1	0	0	0	0
Euphorbia amliphylla	0	0	0.09	0.08	0
Gnidia glauca	0	0.39	0.13	0	0
Maesa lanceolata	0	1.04	0.94	0.52	0.563
Maytenus arbutifolia	0.35	0.82	0.84	0.8	0.25
Myrsine melanophloeos	0	0.04	0.13	0.28	0
Nuxia congesta	0.05	0.39	0.22	0.16	0.313
Pittosporum virdiflorum	0	0.5	0.13	0.32	0.375
Prunus africana	0	0.11	0.19	0.52	0.75
Schefflera abyssinica	0	0	0.03	0.08	1.313
Teclea nobilis	0	0	0	0	0.125
Rosa abyysinica	0	0	0.03	0	0
Hypericum revolutum	0	0	0.06	0	0.063
Galiniera coffeoides	0	0.04	0.06	0.04	0.063

Appendix 12. Basal Area/ha (m^2/ha) of woody species in the community types of the Dry Evergreen Afromontane vegetation

	Basal Area/ha in Comm. types					
Woody species	**C 1**	**C 2**	**C 3**	**C 4**	**C 5**	**Sum**
Acacia abyssinica	24.64	5.62	0.55	0	0.229	5.64
Albizia schimperiana	0	0	0.02	0.35	0	0.08
Allophylus abyssincus	0.099	0.07	0.08	0	2.625	0.36
Bersama abyssinica	0.078	0.14	0.05	0	0	0.06
Buddleja polystachya	0	0	3.77	0.62	0.92	1.25
Canthium oligocarpum	0	0	0	0.52	2.161	0.36
Croton macrostachyus	0	0	0	0.09	0.377	0.06
Dombeya torrida	2.903	3.48	0.89	2.41	0	2.05
Dovyalis abyssinica	0	0	0	0	1.254	0.15
Ekebergia capensis	0	0	0	0	1.786	0.21
Erythrina brucei	0	0.19	0	0	0	0.04
Euphorbia amliphylla	0	0	0.17	0.05	0	0.06
Gnidia glauca	0	0.19	1.12	0	0	0.35
Maesa lanceolata	0	1.49	7.74	1.29	3.602	3.13
Maytenus arbutifolia	1.513	3.27	4.93	1.55	0.329	2.71
Myrsine melanophloeos	0	0.1	0.19	0.12	0	0.1
Nuxia congesta	0	1.5	0.21	0	0.513	0.47
Pittosporum virdiflorum	0	5.15	0.45	2.77	3.802	2.36
Prunus africana	0	0.23	0.25	10.1	5.186	2.85
Schefflera abyssinica	0	0	1.4	26	2.507	6.14
Teclea nobilis	0	0	0	0	0.543	0.06
Rosa abyysinica	0	0	0.25	0	0	0.07
Hypericum revolutum	0	0	0.02	0	0.182	0.03
Galiniera coffeoides	0	0	0.04	0.11	0.152	0.05

Appendix 13. Relative Frequency (RF), Relative Density (RD), Relative Basal Area (RBA) and Important Value Index (IVI) of woody species in the Dry Evergreen Afromontane vegetation

Woody species	RD	RF	RBA	IVI
Acacia abyssinica	9.858	9.39	19.7	38.9
Albizia schimperiana	0.17	0.63	0.27	1.07
Allophylus abyssincus	1.36	2.71	1.26	5.34
Bersama abyssinica	5.552	3.55	0.21	9.31
Buddleja polystachya	3.173	3.97	4.36	11.5
Canthium oligocarpum	2.266	3.34	1.27	6.88
Croton macrostachyus	0.453	0.63	0.22	1.3
Dombeya torrida	2.436	6.26	7.16	15.9
Dovyalis abyssinica	0.623	1.04	0.51	2.18
Ekebergia capensis	0.17	0.63	0.73	1.53
Erythrina brucei	0.113	0.42	0.15	0.69
Euphorbia amliphylla	0.283	1.04	0.2	1.52
Gnidia glauca	2.776	3.13	1.21	7.11
Maesa lanceolata	25.67	16.9	10.9	53.5
Maytenus arbutifolia	28.95	16.9	9.48	55.3
Myrsine melanophloeos	1.87	2.51	0.35	4.73
Nuxia congesta	3.569	5.85	1.64	11.1
Pittosporum virdiflorum	4.136	6.68	8.25	19.1
Prunus africana	3.796	7.1	9.96	20.9
Schefflera abyssinica	1.473	5.01	21.4	27.9
Teclea nobilis	0.227	0.42	0.22	0.87
Rosa abyysinica	0.113	0.21	0.23	0.56
Hypericum revolutum	0.227	0.63	0.09	0.95
Galiniera coffeoides	0.34	1.04	0.17	1.56

Appendix 14. Important Value Index (IVI) of woody species in the community types of the Dry Evergreen Afromontane forest

	IVI in community types				
Woody species	**C 1**	**C 2**	**C 3**	**C 4**	**C 5**
Acacia abyssinica	192.2	48.7	5.13	0	4.109
Albizia schimperiana	0	0	1.07	3.77	0
Allophylus abyssincus	8.314	2.27	1.6	0	26.93
Bersama abyssinica	54.02	4.22	7.4	0	0
Buddleja polystachya	0	0	29.9	14.2	9.575
Canthium oligocarpum	0	0	0	7.57	40.66
Croton macrostachyus	0	0	0	2.47	6.37
Dombeya torrida	16.48	38.8	7.48	13.2	0
Dovyalis abyssinica	0	0	0	0	16.27
Ekebergia capensis	0	0	0	0	11.68
Erythrina brucei	5.595	0.88	0	0	0
Euphorbia amliphylla	0	0	3.76	3.13	0
Gnidia glauca	0	10.7	14.2	0	0
Maesa lanceolata	0	52.7	99.8	29.8	48.1
Maytenus arbutifolia	25.17	59	88.2	57.6	9.986
Myrsine melanophloeos	0	3.03	5.9	13.9	0
Nuxia congesta	2.381	27.5	7.91	7.21	11.74
Pittosporum virdiflorum	0	47	6	22.8	24.8
Prunus africana	0	3.87	7.11	50.9	44.88
Schefflera abyssinica	0	0	7.45	67.4	32.82
Teclea nobilis	0	0	0	0	6.44
Rosa abyysinica	0	0	2.25	0	0
Hypericum revolutum	0	0	2.08	0	2.879
Galiniera coffeoides	0	1.03	2.28	1.75	2.198

Appendix 15. Rank and priority class of woody species in the Dry Evergreen Afromontane vegetation

S. No.	Tree spp.	RF	RD	RBA	IVI	Rank	Priority class
1	*Maytenus arbutifolia*	15.3	32.1	10.24	57.69	1	1
2	*Maesa lanceolata*	18.1	21	9.631	48.79	2	2
3	*Acacia abyssinica*	9.07	11	18.94	39.01	3	3
4	*Prunus africana*	7.34	5.53	14.03	26.9	4	4
5	*Schefflera abyssinica*	5.18	1.13	15.66	21.97	5	4
6	*Pittosporum virdiflorum*	7.34	5.01	9.207	21.56	6	4
7	*Dombeya torrida*	7.99	3.73	8.652	20.37	7	4
8	*Buddleja polystachya*	6.05	3.97	4.936	14.95	8	5
9	*Nuxia congesta*	6.05	4.02	2.051	12.11	9	5
10	*Gnidia glauca*	3.89	3.26	1.229	8.376	10	6
11	*Canthium oligocarpum*	3.46	2.74	1.767	7.962	11	6
12	*Allophylus abyssincus*	2.81	1.75	1.464	6.019	12	6
13	*Myrsine melanophloeos*	2.81	1.75	0.353	4.909	13	6
14	*Dovyalis abyssinica*	0.86	0.76	0.557	2.177	14	6
15	*Euphorbia amliphylla*	0.86	0.8	0.365	2.032	15	6
16	*Albizia schimperiana*	0.65	0.28	0.423	1.355	16	6
17	*Ekebergia capensis*	0.86	0.28	0.114	1.261	17	6
18	*Croton macrostachyus*	0.43	0.38	0.046	0.856	18	7
19	*Bersama abyssinica*	0.43	0.19	0.076	0.697	19	7
20	*Erythrina brucei*	0.22	0.09	0.238	0.548	20	7
21	*Teclea nobilis*	0.22	0.19	0.032	0.437	21	7

Appendix 16. Density/ha of seedling, sapling and matured woody species in the Dry Evergreen Afromontane vegetation (D = Density)

Community 1			
Woody species	**D (Seedling)**	**D (Sapling)**	**D (Mature)**
Acacia abyssinica	400	244.4	244.4
Albizia schimperiana	0	0	0
Allophylus abyssincus	0	0	0
Bersama abyssinica	822.2	711.1	711.1
Buddleja polystachya	0	0	0
Canthium oligocarpum	22.22	0	0
Croton macrostachyus	0	0	0
Dombeya torrida	0	44.44	44.44
Dovyalis abyssinica	0	0	0
Ekebergia capensis	0	0	0
Erythrina brucei	0	0	0
Euphorbia amliphylla	0	0	0
Gnidia glauca	0	0	0
Maesa lanceolata	0	0	0
Maytenus arbutifolia	211.1	400	400
Myrsine melanophloeos	0	0	0
Nuxia congesta	0	0	0
Pittosporum virdiflorum	0	33.33	33.33
Prunus africana	0	0	0
Schefflera abyssinica	0	0	0
Teclea nobilis	0	0	0
Rosa abyysinica	0	0	0
Hypericum revolutum	0	0	0
Galiniera coffeoides	33.33	11.11	11.11
	1489	1444	1444
Community 2			
Woody species	**D (Seedling)**	**D (Sapling)**	**D (Mature)**
Acacia abyssinica	95.24	71.43	71.43
Albizia schimperiana	0	0	0
Allophylus abyssincus	0	0	0
Bersama abyssinica	0	47.62	47.62
Buddleja polystachya	87.3	0	0
Canthium oligocarpum	0	0	0
Croton macrostachyus	0	0	0
Dombeya torrida	420.6	285.7	285.7
Dovyalis abyssinica	0	0	0

Ekebergia capensis	0	0	0
Erythrina brucei	0	0	0
Euphorbia amliphylla	0	31.75	31.75
Gnidia glauca	0	0	0
Maesa lanceolata	2183	2230	2230
Maytenus arbutifolia	0	0	0
Myrsine melanophloeos	0	0	0
Nuxia congesta	31.75	0	0
Pittosporum virdiflorum	761.9	579.4	579.4
Prunus africana	0	23.81	23.81
Schefflera abyssinica	0	0	0
Teclea nobilis	0	0	0
Rosa abyysinica	0	0	0
Hypericum revolutum	0	0	0
Galiniera coffeoides	0	0	0
Community 3			
Woody species	**D (Seedling)**	**D (Sapling)**	**D (Mature)**
Acacia abyssinica	0	27.78	27.78
Albizia schimperiana	0	0	0
Allophylus abyssincus	48.61	20.83	20.83
Bersama abyssinica	0	0	0
Buddleja polystachya	444.4	145.8	145.8
Canthium oligocarpum	0	0	0
Croton macrostachyus	0	0	0
Dombeya torrida	0	13.89	13.89
Dovyalis abyssinica	0	0	0
Ekebergia capensis	0	0	0
Erythrina brucei	0	0	0
Euphorbia amliphylla	0	13.89	13.89
Gnidia glauca	0	55.56	55.56
Maesa lanceolata	2597	1896	1896
Maytenus arbutifolia	3722	4014	4014
Myrsine melanophloeos	0	0	0
Nuxia congesta	0	0	0
Pittosporum virdiflorum	0	13.89	13.89
Prunus africana	34.72	0	0
Schefflera abyssinica	0	13.89	13.89
Teclea nobilis	0	0	0
Rosa abyysinica	55.56	0	0
Hypericum revolutum	201.4	0	0

Galiniera coffeoides	0	0	0
Community 4			
Woody species	**D (Seedling)**	**D (Sapling)**	**D (Mature)**
Acacia abyssinica	0	0	0
Albizia schimperiana	0	0	0
Allophylus abyssincus	0	0	0
Bersama abyssinica	0	0	0
Buddleja polystachya	17.78	71.11	71.11
Canthium oligocarpum	0	0	0
Croton macrostachyus	0	0	0
Dombeya torrida	0	62.22	62.22
Dovyalis abyssinica	0	0	0
Ekebergia capensis	0	17.78	17.78
Erythrina brucei	0	0	0
Euphorbia amliphylla	0	17.78	17.78
Gnidia glauca	0	0	0
Maesa lanceolata	0	0	0
Maytenus arbutifolia	364.4	266.7	266.7
Myrsine melanophloeos	0	0	0
Nuxia congesta	0	0	0
Pittosporum virdiflorum	124.4	0	0
Prunus africana	204.4	462.2	462.2
Schefflera abyssinica	133.3	391.1	391.1
Teclea nobilis	0	0	0
Rosa abyysinica	0	0	0
Hypericum revolutum	0	0	0
Galiniera coffeoides	0	0	0
Community 5			
Woody species	**D (Seedling)**	**D (Sapling)**	**D (Mature)**
Acacia abyssinica	49.38	0	0
Albizia schimperiana	0	0	0
Allophylus abyssincus	1173	308.6	308.6
Bersama abyssinica	148.1	61.73	61.73
Buddleja polystachya	0	0	0
Canthium oligocarpum	444.4	0	0
Croton macrostachyus	0	0	0
Dombeya torrida	0	0	0
Dovyalis abyssinica	61.73	172.8	172.8
Ekebergia capensis	0	0	0

Erythrina brucei	0	0	0
Euphorbia amliphylla	0	0	0
Gnidia glauca	0	0	0
Maesa lanceolata	345.7	1185	1185
Maytenus arbutifolia	666.7	765.4	765.4
Myrsine melanophloeos	0	0	0
Nuxia congesta	0	0	0
Pittosporum virdiflorum	0	0	0
Prunus africana	0	160.5	160.5
Schefflera abyssinica	0	0	0
Teclea nobilis	24.69	0	0
Rosa abyysinica	0	0	0
Hypericum revolutum	0	0	0
Galiniera coffeoides	0	0	0

Addis Ababa University

Graduate Programmes

Plant Biology and Biodiversity Management

Declaration

I, the undersigned, declare that this thesis, entitled "Ecological Study of the Vegetation in Choke-Koso Ber Mountain Range, Northwest Ethiopia" is my original work and it or part of it has not been presented or submitted to any other institution. All sources of the materials used for the thesis have been duly acknowledged.

Getaneh Belachew Haile

Signature: ______________________

Date of submission: ______________

I confirmed that the work reported in this thesis was carried out by the candidate under my supervision.

Advisor's Name: Prof. Zerihun Woldu

Signature: ___________________

Date: _______________________