Vegetation Ecology and Land Use/ Land Cover Changes in Selected Afromontane Forests Along Gibe–Omo Watershed, Southwest Ethiopia

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Abstract

This study was aimed to investigate plant diversity and community analyses of the Afromontane forests at Tiro Boter Becho (TBB) and Chebera Churchura National Park (CCNP) and analyze LU/LC changes of the two study areas. Systematic sampling technique was applied to vegetation and environmental data collection. Vascular plants encountered in each plot were recorded and identified. In addition, soil samples were taken from each plot and analyzed for pH, organic matter, cation exchange capacity, total nitrogen, available phosphorus and texture. Land use land cover changes of the two study sites were analyzed from the period 1984–2015 using geographic information system and remote sensing techniques. 204 and 144 plant species were recorded from TBB and CCNP respectively. Five and four plant communities were identified at the Afromontane forests of TBB and CCNP respectively. The density of woody species was 1902 stems.ha^{-1} in TBB and 1562 stems.ha^{-1} in CCNP. Whereas, the Basal area of woody species was 72.98 m^{2}ha^{-1} in TBB and 73.81 m^{2}ha^{-1} in CCNP. Four LU/LC types were identified in TBB and five LU/LC types were identified in CCNP. In the period of 1984–2000, Forest and Agriculture & Settlement showed increasing trends in TBB. But Woodland and Shrub/Bushland showed decreasing trends. In the period 2000–2015, Agriculture & Settlement and Shrub/Bushland showed increasing trends. But Forest and Woodland showed a remarkable loss. In CCNP, Forest, Grassland and Agriculture & Settlement showed increasing trends in the period of 1984–2000. But Woodland and Water body showed decreasing trends. In the period 2000–2015, Agriculture & Settlement, Grassland and Water body showed increasing trends. Whereas Forest and Woodland showed decreasing trends. A decreasing trend in vegetation and increasing trend in Agriculture and Settlement is an indication of high demand of land for cultivation and settlement. Integrated watershed management approach should be in place to manage the entire watershed. Furthermore, effective enforcement of forest laws/policies, fair involvement of local communities in forest management, delineation of the forest buffer zone and improve the use of modern stoves for efficient energy consumption must be carried out at a local level to ensure the sustainability of natural forest.

Key Words/phrases: Afromontane forest, Chebera Churchura National Park, Land use/Land cover change, Plant Community and Diversity, and Tiro-Boter-Becho

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ACRONYMS

a.s.l.	above sea level
BA	Basal Area
CCA	Canonical Correspondence Analysis
CCNP	Chebera Churchura National Park
CEC	Cation Exchange Capacity
CRGE	Climate Resilient Green Economy
DBH	Diameter at Breast Height
DCA	Redundancy analysis
EFAP	Ethiopian Forestry Action Program
FAO	Food and Agriculture Organization
FDRE	Federal Democratic Republic of Ethiopia
GIS	Geographic Information System
GPS	Global Positioning System
ha	Hectare
IBC	Institute of Biodiversity Conservation
IUFRO	International Union for Forestry Research Organization
IVI	Important Value Index
km	Kilometer
LU/LC	Land Use/Land Cover
NCS	National Conservation Strategy
NDVI	Normalized Difference Vegetation Index
NFPAs	National Forest Priority Areas
NMA	National Meteorological Agency
OFWE	Oromiya Forest and Wildlife Enterprise
OM	Organic Matter
PGR	Plant Genetic Resources
pH	Measure of Hydrogen ion
QGIS	Quantum Geographic Information System
ROI	Region of Interest
TBB	Tiro Boter Becho
UNDP	United Nations Development Programme
USGS	United States Geographical Survey
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER ONE

1. Introduction

1.1 Background of the Study

Ethiopia, a country with a total area of 1.1 million km^2 is located in the northeastern part of Africa. Ethiopia's topographical diversity encompasses high and rugged mountains, plateaus, and deep gorges with rivers and rolling plains (PGR, 1995; Zerihun Woldu, 1999). The altitudes ranges from 110 meter below sea level at the Danakil depression, in the northeast to 4530 m.a.s.l, to the Simien Mountains in the north.

Tropical forests are the most diverse ecosystems and are reservoirs of biodiversity (Fangliang et al., 1996). Ethiopia possesses the fifth largest floral composition in tropical Africa (Eshetu Yirdaw, 2001). The topographic and altitudinal diversity have made the country to have diverse ecological conditions, which in turn contributed for its diverse biological resources with endemic elements (PGR, 1995; Zerihun Woldu, 1999). Hedberg (2009) and Ensermu Kelbessa and Sebsebe Demissew (2014) indicated that, the current estimate of higher plants is about 6,000 species with 10% endemism.

Forests are among main resources of the country and having wider range of biodiversity, and are often vital to livelihood strategies of local communities through provision of environmental services and socioeconomic benefits. Pearce and Pearce (2001); Tadesse Woldemariam, (2003); World Bank (2004); and Feyera Senbeta (2006) stated that, the forests of the country are providing several ecosystem services including regulation of rainwater runoff and drought, control of pests and disease, purification of air and water, plant pollination, soil formation and maintenance, seed dispersal and nutrient cycling, maintaining biodiversity, provide ecological and ethno–botanical uses, climate stabilization (through carbon sequestration), and regulating extremes of temperature and wind.

As part of the Gibe–Omo watershed, the Afromontane forests of Tiro Boter Becho state forest and Chebera Churchura National Park play great roles in serving as sources of water for Gibe and Omo Rivers, flood retention and ground water recharge.

Today, forests worldwide is facing unprecedented pressures (FAO, 2015). World Bank (2004) also reported that forest ecosystems are being converted to other land uses; freshwater resources are over utilized affecting the normal flow rates and recharge; and pasturelands are overused and agricultural soils are being degraded. Similarly, the natural forests in Ethiopia are under high pressure due to ever increasing human population despite the services they provide (Kumelachew Yeshitela, 2008).

Forest inventory and examination of land use/land cover changes are vital tools for forest management (Maureen and Andrew, 2004). Therefore, this study will bring information required to design strategies needed for sustainable forest management (including restoration, reforestation, and combat forest degradation) in the area.

1.2 Statement of the Problem

Rapid increase in global temperatures may cause regional and global changes in climate that could have significant impacts on human and natural systems. Forests play both ecological and regulatory roles supportive to overcome the effect of climate change. Several small rivers, which drain into Gibe and Omo Rivers, originate from mountains covered by the Afromontane forests at TBB and CCNP respectively. These forests play important regulatory role in hydrological processes of the area. The Afromontane forests in the area capture and store rainfall and moisture, maintain water quality, regulate river flow, reduce erosion, and protect against landslides. More specifically, the Afromontane forests of TBB and CCNP are draining water to Gibe and Omo rivers where dams are constructed for hydroelectric power generation. These forests have a great use in reducing soil erosion that induces heavy silt loads into the dam. In the absence of these forests, Gibe and Omo rivers may gradually change into intermittent rivers and progressively into dry river beds. In addition, the role of Afromontane forests at TBB and CCNP in climate change regulations could not be underestimated since the forests in the country have tremendous roles in building climate–resilient green economy. The vegetation studies and LU/LC changes taking place in these Afromontane forests have not been carried out.

One of the vital tools for forest management is forest inventory (Maureen and Andrew, 2004). According to Kershaw (1973), vegetation studies promote designing and employment of appropriate conservation and management plan for sustainable use of resources. Careful analysis of vegetation provides relevant information about its present situation and ecological status (Goldsmith et al., 1986). It also helps for monitoring future changes in species composition. Changes in land cover have caused most pressing environmental issue in recent decades (FAO, 2015). Factors that cause changes in LULC are essential for predicting future changes or development of management strategies and policies to ameliorate or prevent further decline of natural resources. This study aims to investigate the diversity of the Afromontane forests of TBB and CCNP, and analyzing the LU/LC changes of these area.

1.3 Objective of the Study

1.3.1 General Objective

The main objective of this study is to study on floristic, structure, and plant diversity of the Afromontane forests of Tiro-Boter-Becho (TBB) and Chebera Churchura National Park (CCNP); and land use/land cover changes in the two study areas.

1.3.2 Specific Objectives

The specific objectives are:

- to study the plant diversity and composition of the Afromontane forests of TBB and CCNP
- to describe vegetation structure of the Afromontane forests of TBB and CCNP
- to study the land use/land cover changes of the study areas

1.4 Research Questions

In order to realize the aforementioned research objectives, the following research questions were raised:

- What are the plant species existing at the Afromontane forests of TBB and CCNP?
- What plant communities are identified at the two Afromontane forests?
- Which environmental factors significantly affect the distribution of plant communities at the Afromontane forests of TBB and CCNP?
- What is the regeneration status of the Afromontane forests of TBB and CCNP?
- What does the land use/land cover change of the study areas look like?

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Afromontane Forests of Ethiopia

Edwards and Ensermu Kelbessa (1999) expressed that Ethiopia is an important regional center of biodiversity. Studies by EFAP (1994), Demel Teketay (1999), Zerihun Woldu (1999), and IBC (2005) show that, varied topography, the rift valley, and the surrounding lowlands have given Ethiopia a wide spectrum of habitats, plant diversity, and large number of endemics. The Afromontane forests of Ethiopia are part of Eastern Afromontane Biodiversity Hotspots, one of the 34 regions globally important for biodiversity conservation (Conservation International, 2009). Most Afromontane communities are found above 2000 m, but they can occur as low as 1200m above sea level in some places (White, 1983). The Ethiopian highlands (land areas above 1500 m.a.s.l. with associated valleys) comprise over 50% of the Eastern Afromontane Hotspot and over 40% of the Horn of Africa Hotspot (Tamirat Bekele, 1994; Yalden, 1983) are however, among the most threatened Hotspot areas in the world. Afromontane forests of Ethiopian highlands contain the only forest ecosystem with wild *Coffea arabica* populations worldwide. Despite its importance, the Afromontane forests of Ethiopia are being cleared and degraded at an alarming rate due to several social, economic, and political factors (Feyerea Senbeta and Manfred, 2006).

Many species common in Afromontane forests such as trees of the genera *Podocarpus* and *Juniperus* have economic importance (Tamirat Bekele, 1993). Historical records show that 35–40% of the total land area of the country might have once been covered with natural forest (von Breitenbach, 1961, 1962; and EFAP, 1994). However, this forest resource was later reduced to 4.8 % in 1973 (Reusing, 1998), 4.4% by 1960 (von Breitenbach, 1962), and 4 % in 2000 (Earth Trends (2003). Although a forest resource assessment estimated Ethiopia's forest cover at 11% (FAO, 2010), the Ethiopian government claims to reach 15 % due to the various multifaceted natural resource conservation, reforestation and other related activities carried out during the past decades (Sara Shibeshi, 2015).

Destruction of the remnant high forests continues at an estimated rate of 150,000 - 200,000 ha per year (EFAP, 1994; Reusing, 1998). As evidence, in the highlands of northern Ethiopia, remnants of the original Afromontane forest vegetation are largely restricted to church yards and other sacred groves in a matrix of cropland and semiarid degraded savanna (Aerts, 2006). This is because highlands of Ethiopia, in contrast to most mountain systems outside Africa, are very suitable for human inhabitation/settlement. This population pressure on the highlands accompanied by sedentary agriculture, extensive cattle herding activities and socio-political instability, has resulted in heavy deforestation, forest fragmentation, and loss of biodiversity and impoverishment of ecosystems in general (Eshetu Yirdaw, 2002).

Many scholars have classified the Ethiopian vegetation into various categories which can even split into smaller units (Logan,1946; Pichi-Sermolli,1957; von Breitenbach, 1963; White,1983; Friis, 1986; Friis,1992; Sebsebe Demissew *et al.*, 1996; Zerihun Woldu, 1999; and Friis and Sebsebe Demissew, 2001). Pichi-Sermolli (1957) recognized 24 vegetation units for the whole country and von Breitenbach (1963) proposed seven broadly defined units, which were further subdivided into smaller associations. Gilbert (1986) argued that some vegetation types described by

Pichi- Sermolli hardly differed from each other, while others have been oversimplified. Friis *et al*. (1982) pointed out that von Breitenbach's associations lack essential information on localities and distribution. According to White (1983) vegetation classification, the country has four of the regional centres of endemism: Sudanian Regional Centre, Somalia-Maasai Regional Centre, Afromontane Regional Centre and Afroalpine Regional Centre. These are very broad categorizations of the vegetation of Ethiopia with ‘centers of endemism’ as the main emphasis.

Moreover, Sebsebe Demissew *et al*. (1996) broadly categorized the vegetation of Ethiopia into nine major groups. These include Afroalpine and Sub-Afroalpine vegetation, dry evergreen montane forest, moist evergreen montane forest, wetlands, evergreen scrub, *Combretum-Terminalia* woodland, *Acacia-Commiphora* woodland, lowland dry forest, and lowland semi-desert and desert areas. Similarly, Zerihun Woldu (1999) also categorized the Ethiopian vegetation into nine broad vegetation types. These are Afroalpine and Sub–Afroalpine, dry evergreen montane forest and grassland complex, moist evergreen montane forest, *Acacia – Commiphora* woodland, *Combretum – Terminalia* woodland, lowland semi–evergreen forest, desert and semi–desert scrubland, and wetlands and riparian vegetation. These attempts have all contributed considerably towards the understanding of the vegetation types of Ethiopia.

Very recently, the Atlas of the Potential Vegetation Map of Ethiopia (Friis *et al*., 2011) shows the distribution of twelve potential vegetation types that was mapped using environmental parameters and GIS-methodology at the scale of 1:2,000,000. These vegetation types have been described and further divided into a number of subtypes, including desert, semi-desert, deciduous bush-lands and woodlands, evergreen Afromontane forests and grasslands, transitional rainforest, Ericaceous and Afroalpine vegetations, riverine vegetation, various types of freshwater lake- and swamp-vegetation, as well as salt-lakes and salt-pans. The vegetation types classified here are based on information from previous literature and field experience of the authors as they have life-long work experience on Ethiopian vegetation. An analysis of the information for about 1300 species of woody plants in the Flora of Ethiopia and Eritrea have been made by the authors. Accordingly, of the vegetation types and subtypes described in the text, fifteen units that have large enough extension are mapped and defined in relation to topographic features such as altitude, rivers and lakes and rainfall.

Among the general vegetation studies mentioned above, some are giving a particular emphasis in forests and forest types. Both Logan (1946) and Pichi-Sermolli (1957) provided a general outline of Ethiopian forest vegetation, comprising three distinct forest types: Montane Dry Evergreen Forest, Montane Moist Evergreen Forest and Bamboo Forest. Von Breitenbach (1963) recognized more forest types according to their dominant species and grouped them into two very broad categories such as Lower and Upper-Highland Forests. The most important surveys of Ethiopian forests are those by Friis *et al*. (1982) and Friis (1992).

2.2 Moist Evergreen Afromontane Forest

The Afromontane forests on the Ethiopian highlands can be broadly divided into dry montane forests and moist montane forests. The dry montane forests are dominated by hard leaved evergreens, such as *Juniperus procera*, *Podocarpus falcatus,* and *Olea europaea* subsp. *cuspidata*. While the moist montane forests are characterized by large broad leaved and soft leaved species like *Aningeria adolfi-friederici*, *Olea* *welwitschii*, *Olea hochsteterii*, and *Croton macrostachyus* (Sebsebe Demissew *et al.*, 1996; Tamirat Bekele, 1994). *Arundinaria alpina* stands are also found at humid highland elevation areas.

Moist Evergreen afromontane forest (MAF) is the major remnant forest in the country. Different authors have given different names for this forest vegetation; (Afro) montane rainforest (Friis, 1992), moist montane forest or moist montane evergreen forest (Friis, 1986; Sebsebe Demissew *et al*., 1996; Zerihun Woldu, 1999). According to Sebsebe Demissew and Friis (2009), this forest type was considered to consist of two subtypes: Subtype I (Afromontane Rainforest, where wild coffee are found between 1500 and 2600 m a.s.l) and Subtype II (Transitional Rainforest between 450 and 1500 m a.s.l bordering the *Combretum-Terminalia* woodlands on the western escarpments of the Ethiopian highlands in the floristic regions of IL and KF). Recent quantitative assessments demonstrate the presence of different regional moist forest assemblages and question whether the general altitudinal cut-off level at 1500 m a.s.l. is the most decisive factor for floristic variations (Tadesse Woldemariam, 2003; Feyera Senbeta, 2006; Schmitt *et al*., 2010). The moist evergreen Afromontane forests remaining are mainly found at altitudes between 500 and 3000 m in the southwest and southeast of the country and are characterized by steep slopes and rugged topography (Friis *et al*., 2011).

The Ethiopian Afromontane forests are belong to the least explored and least protected eco-regions in Africa (Tadesse Woldemariam *et al.*, 2008). This is surprising given the fact that these areas in Ethiopia have been recognized as global biodiversity conservation priority areas and centers for plant diversity (Barthlott *et al.*,

1999) but also for other groups of organisms such as Endemic Bird Areas (ICBP, 1992).

According to vegetation classification of White (1983), Moist Evergreen Afromontane forest was named as Afromontane Rainforest which is very similar in structure and physiognomy to certain types of Guineo-Congolian lowland rainforest. At the species level, however, it is almost completely different but many of its species are closely related to Guineo-Congolian species or have their closest relatives elsewhere in the lowland tropics (Chapman & White, 1970). In Ethiopia, the montane moist forest ecosystem comprises high forests of the country mainly the southwest forests, which are the wettest, and also the humid forest on the southeastern plateau known as the Harenna forest. The highlands in the southwest of the country form the upper catchments of several important rivers such as the Baro and Akobo (tributaries of the Nile) and the Omo iver. The forests in this region do not only play a major role in water regulation of these rivers but are also of significance for conserving biodiversity. They are floristically related to other Afromontane forests, especially in eastern Africa, and harbour unique plants (Friis *et al*., 1982).

Floristically, MAF is a moderately diverse vegetation type, with a low number of unique woody species, subspecies, and varieties. The highest number of woody species, subspecies and varieties are shared with dry evergreen Afromontane forest and grassland complex (DAF), Riverine vegetation, and transitional rainforest (Friis *et al*., 2011). Several authors (Mooney, 1963; Chaffey, 1979; Mesfin Tadesse, 1986; Friis, 1986 and 1992; Lisanework Nigatu and Mesfin Tadesse, 1989; Zerihun Woldu *et al*., 1989; Kumlachew Yeshitila, 1997; and Abreham Assefa *et al.*, 2014) studied the composition and population structure of this type of forest vegetation and described them on floristic basis. According to Friis (1992), it occurs in the southwestern part of the Ethiopian highlands at altitudes between 1500 and 2600 m, at annual rainfall between 700 and 1500 mm. However, as to White (1983), the mean annual rainfall lies mostly between 1250 and 2500 mm, but is sometimes higher. There is usually a dry season lasting from one to five months, but dry season mists are frequent. This may explain the fact that upland rainforest is often much less deciduous than lowland semi-evergreen rainforest experiencing a similar rainfall. Apart from secondary species, only a few of the larger tree species such as *Pouteria adolfi-friederici* and *Entandrophragma excelsum* lose their leaves and then only for few days.

2.3 Diversity and Composition of Moist Afromontane Forest

This forest is home to various endemic and indigenous plants though poor in endemicity compared to DAF. Low diversity in endemic plant species, however, is a common feature of all montane moist forests of Ethiopia (Friis and Sebsebe Demissew, 2001) rather they are important wild gene pools of few important plants for food and agriculture as well some of them are *Coffea arabica*, *Piper capense, Aframomum corrorima.* For instance, Yayu forest is poor in the number of plant species endemic to Ethiopia. Only three endemic species namely: *M. ferruginea, Phyllanthus limuensis,* and *Vepris dainelli* were recorded in the area (Tadesse Woldemariam *et al.,* 2008). Moreover, Ensermu Kelbessa and Teshome Soromessa (2008) listed a total of 243 plant species belonging to 85 families from the Bonga forest. Of these, 66 families were angiosperms, 2 were gymnosperms, and 17 monilophytes (ferns). The region is recognized as biodiversity hotspot of global interest with *Coffea arabica* as flagship species (Tadesse Woldemariam *et al*., 2000).

It is reputed as the area of origin for this species, and there is a long history of forest coffee providing an environmental income to local people (Schmitt, 2006; Wiersum, 2010).

The structural diversity in the forest also allows both animals and plants to occupy different ecological niche. The high forests are not only diverse in their composition but hold also important genetic components and populations of wild coffee and several associated economic plant species. Previous study of the montane moist forests in southwest by Kumlachew Yeshitila (1997) had shown that more than 160 vascular plant species were recorded. This forest vegetation was stratified into four different layers namely; upper canopy, middle canopy, shrub layer and the ground layer. The upper canopy is occupied the spectacular emergent trees of *Pouteria adolfi-friederici* (Friis, 1992). Other characteristic species in the canopy include *Olea capensis* subsp. *welweitschii* and subsp *hochestetteri*, *Prunus africana*, *Albizia schimperiana*, *Milletia ferruginea* and *Celtis africana*. Moreover, species such as *Polyscias fulva*, *Schefflera volkensii*, *Schefflera abyssinica*, *Bersama abyssinica*, *Mimusops kummel* are also associated to it. Middle canopy species include *Croton macrostachyus*, *Cordia africana*, *Dracaena steudneri*, *Syzygium guineense* subsp. *afromontanum*, *Sapium ellipticum*, *Ilex mitis*, *Erythrina brucei*, and *Rothmannia urcelliformis*. The shrub layer consists of species of *Coffee arabica*, *Galiniera saxifraga*, *Teclea nobilis*, *Ocotea kenyensis*, *Clausena anisata*, *Maesa lanceolata* and *Maytenus* spp.

The Woody climbers are *Urera hypselodendron*, *Landolphia owarensis*, *Embelia schimperi*, and *Jasminum spp*. The ground cover is comparatively lush, and rich in ferns, grasses and herbaceous plants such as *Acanthus*, *Justicia*, *Peperomia*, *Galinsoga*, *Impatiens*, and *Urtica*. *Lianas* are present and about several species have been recorded and *Arundinaria alpina* is not uncommon at higher altitudes in this area (Friis, 1992). The montane moist forest ecosystem is distinguished also by supporting luxuriant growing epiphytes *Canarina*, *Orchids*, *Scadoxus,* and fern plants such as *Platycerium* and *Drynaria*. Mosses also occur in the wettest portion of forests associated to major branches and barks of trees. *Podocarpus* is never a single dominant and becomes gradually more infrequent towards the southwest in *Kaffa* and *Ilubabor* as the rainfall increases, while the *Pouteria adolfi-friederici* becomes more prominent in the same direction. The drier parts of these forests are floristically very similar to those in the humid parts of the central highlands. The more or less continuous canopy consists of medium sized trees 10-30 m tall. The smaller trees and large shrubs form a discontinuous stratum. The most humid forests have dense stands of tree ferns (*Cyathea*) in the ravines.

In general, the southwestern receives the highest amount of rainfall in the country. Some of the good examples of the moist forests literally included in high forests of Ethiopia include: *Tiro-Boter-Becho forest, Belete-Gera, Yayu, Sigmo-Gatira, Harenna-Kokosa in Oromia Region and the Masha-Anderacha, Bonga, Godere* forests in Southern Regions. These forests are recognized as high forests with closed continuous canopy cover. Most of the forests in the southwestern plateau which seem to be intact from above canopy are *Coffee* managed forests highly encroached by humans. The trees have been selectively felled for timber, construction, expansion of agriculture as well as *Coffee* and *Tea* plantations (Feyera Senbeta, 2006; Tadesse Woldemariam *et al.*, 2008).

2.4 Importance of the Forest of Ethiopia

Forests also sustain a range of economic activities in the world and act as a source of food, medicine and fuel for more than a billion people (FAO, 2015). Forest ecosystems and biodiversity more generally, are being considered for a wide variety of useful services they provide for human wellbeing (MEA, 2003). The services provided by the natural forest include provisioning services (e.g. food, fiber, fuel, water), regulating services (e.g. climate, floods, disease, waste and water quality), cultural services (e.g. recreation, aesthetic enjoyment, tourism, spiritual and ethical values), and supporting services necessary for the production of all other ecosystem services (e.g. soil formation, photosynthesis and carbon sequestration, nutrient cycling). Supporting services are services that provide benefits outside the forest ecosystem itself. For examples watershed protection and natural water filtration benefits people in downstream and carbon sequestration benefits the entire global community by reducing climate change (Bishop, 1999). However, the extent to which human beings depend upon the natural forests for ranges of biological and chemical processes is not well accounted.

Forestry is as one of the economic sectors in Ethiopia, and is closely linked to economic growth and wellbeing of local communities. It is the one among four pillars in the Climate Resilient Green Economy (CRGE) strategy (FDRE, 2011; UNDP, 2014). However, the value of forest ecosystem service is currently not adequately captured under system of national account and its contribution to the national economy is not estimated (UNDP, 2016). Moreover, only commercial timber is accounting for Ethiopian economy (UNDP, 2016).

2.5 Threats to Afromontane Forests

Human beings are demanding more goods and services from natural forest beyond their capacity to meet their need. Human induced disturbances such as fragmentation and habitat loss are strongly influencing the regeneration success of plant species, and determine the vegetation structure and composition of forests (Cabin *et al*., 2002; Cotler and Ortega–Larrocea, 2006). According to Demel Teketay (1992) and Tamrat Bekele (1994), growth in human populations and prosperity in Ethiopia translates into increased conversions of natural forest to agricultural, industrial, or residential use.

The forest cover of Ethiopia in the past was expected to be much larger than the present. Major deforestation incidents took place all over Ethiopia towards the beginning of the twentieth century (Melaku Bekele, 2003; EFAP, 1994). Statistical figures regarding Ethiopian forests indicate a continuous decline from the original 35% forest cover in 1950 (von Breitenbach, 1961, 1962; and EFAP, 1994) to 2.4% in 1992 (NCS, 1990; Sayer *et al*., 1992). FAO (2002) estimates the annual rate of deforestation to be between 150,000ha – 200,000ha. From 1990 – 2010 alone, 2.65% of the forest cover of the country was deforested (FAO, 2010). Deforestation affects biodiversity and natural habitats and degrades natural resources. Von Breitenbach (1963) stated that, the greatest threat to montane forest is the destruction caused by deforestation, fire, expansion of agriculture and overgrazing which leads to depletion of standing stock.

Growing population is one of the reason for increasing deforestation, which is leading the country to lose its forest resources (Zewdu Eshetu and Yitebitu Moges, 2010). As the population continues to grow, demand for agricultural land increases. This results in permanent change of forest to other land uses such as agriculture, grazing, new settlements, and infrastructure. This alarming rate of deforestation will results in fuel wood crisis, loss of flora and fauna, loss of genetic diversity, loss of fertile soil and reduced agricultural productivity.

Even though the depletion of forest stocks of the country is not well captured, the natural forests are vanishing at an alarming rate due to extensive deforestation (Hurni *et al*., 1987; Mulugeta Lemenih and Demel Teketay, 2006; and Shibru Tedla, 1995). Often the decisions made on the forests do not take due consideration of the interests of stakeholders, especially communities who are dependent on the local resources. As a result, uncontrolled expansion of agriculture and grazing coupled with the illegal harvesting of the forest and other forest products has been threatening normal ecological functions of the forest ecosystems in many parts of the country (Chaffey, 1980; and Shibru Tedla, 1995). Moreover, lack of integration of the local people living around the conservation areas in the conservation efforts, and absence of law enforcement system triggers change that results in decline of diversity and abundance of natural vegetation (Mulugeta Lemenih and Demel Teketay, 2006; Demel Teketay, 1999).

Similar to other forested areas of the country, the remaining high natural and coffee forests in the southwest of Ethiopia are continuously threatened by anthropogenic activities such as agricultural encroachment, extraction of timber and fire (Melaku Bekele, 1992; and Feyera Senbeta, 2006). For instance, according to Gatzweiler (2007), coffee forest cover in southwest Ethiopia was reduced by 11% from 1973–1987. This period was characterized by resettlement program and the expansion of state farms. It was also indicated that, 24 % forest loss was due to conversion of 10,128 ha of high forests into coffee plantations. In later periods, forests continued to be converted to agro-forestry systems, agricultural land and settlement areas. There were migration and settlement of landless people from densely populated and drought affected parts of the country in areas covered by forest in search of agricultural land. In addition, investment activities in forested areas and conversion of natural forests into commercial plantations such as coffee and tea plantations in southwest Ethiopia have contributed to the destruction of forests (Kumelachew Yeshitela, 2001). These incidences have accelerated the rate of deforestation in the area. The major reason for the failure to conserve natural forest is that their vulnerability and their values are not fully realized (World Bank, 2004; United Nations, 2013).

2.6 Conservation Status of Forest Resources

Afromontane forests are very important and well known for maintaining threatened species such as *Prunus africana* and *Canarina abyssinica,* and for other ecosystem services. Very recently, increasing demand for land is in conflict with biodiversity conservation in the country (Shibru Tedla and Kifle Lemma, 1998; Young, 2012). Even though the natural forests of the country are under enormous pressure from the growing demands of resources, the Government of Ethiopia has made an effort to manage forests. Among the attempts done for conservation are establishment of number of protected areas that may or may not incorporate the montane forests (parks, NFPAs, wildlife sanctuaries, reserves, community conservation areas) covering about 2.7% of the country (with main focus on larger fauna). These protected areas however have been suffered severe damage during the war or during its immediate aftermath. The parks have not been legally gazetted except very few which was established very earlier.

In addition, 58 most important natural forests were identified and established as National forest priority areas (NFPAs), within the high forest areas with the objective to implement an integrated forest management system (i.e. production, protection and biological conservation services) (EFAP, 1994; Zerihun Woldu, 1999; and FAO, 2002). The NFPAs were established in 1988 comprising of natural forests, plantations, and non-forested lands. Among the NFPAs designated for protection the moist evergreen montane forest ecosystem include *Harenna-Kokossa, Godare (Gambella), Gebre Dima, Setema, Sigmo-Geba, Yayu, Babya-Folla, Belete-Gera, Tiro-Boter-Becho, Masha-Anderacha, Bonga* and *Sheko* forests. In some of the NFPAs there was no natural forests remain and the forest stands have been partly deforested or severely degraded in quality and quantity (Reusing, 1998). The present management of the high forest fails to achieve its conservation objective due to absence of effective forest policy, lack of appropriate institutional setup, and lack of legal status of NFPAs. For example, none of the National Forest Protection Areas (NFPAs) have legal protection any more. At present, except for the *Menagesha Suba* Forest, all Forests designated under NFPAs are under Regional Governments. Moreover, lack of accountability and commitment from government and expansion of investment in forested areas have aggravated the decline of forests in the country.

The land tenure system is a major factor behind the poor adoption of forest conservation and management practices. Repeated studies have confirmed that land security enhances proper land management and increased productivity. When the state administers the land, farmers may not feel secure enough to spend their time in soil protection and land improvement activities. Moreover, with growing population pressure, the degree of land fragmentation continuously increases; this aggravates tenure insecurity as well as land degradation, with consequent degradation in environmental resources and productivity such as forest degradation.

On the other hand, the most important of the conservation areas in Ethiopia is the Bale Mountains National Park, a formal national park and it is yet to be officially gazetted. This Key Biodiversity Area harbors the finest and most intact remnants of the highlands' original vegetation (Young, 2012). These mountains are also home to four threatened endemic species, and to more than half of the global population of the Ethiopian wolf (Conservation International, 2009; Young, 2012).

Reforestation programs resulted in the planting of millions of seedlings in community forests throughout Ethiopia. A number of NGOs, which had to organize their activities through local associations, supplemented government efforts to rehabilitate Ethiopia's forests. However, critics maintain that both systems caused communal resources to be developed at the expense of private needs. As a result, reforestation programs did not perform well throughout the country. Seedling survival rates were as slow as 10 percent in some areas, largely because of inadequate care and premature cutting by nearby residents (McKee, 2007).

2.7 Vegetation Ecology and Plant Communities

Vegetation Studies

Vegetation of an area can be described by its physiognomy and floristic characteristics. Kuchler and Zonneveld (1988) express physiognomy as the overall appearance or morphological characteristics of vegetation. The broad features of the vegetation such as the growth forms and/or the life form of dominant species within a plant community are described using the physiognomy of that particular vegetation.

Physiognomic characterization is a means to describe and characterize vegetation fastly, as it does not require much floristic detail about the vegetation. It is mainly used for conducting a reconnaissance type of vegetation survey to cover large geographical areas in a limited period. Physiognomic characterization is not effective in detecting spatial and temporal changes of vegetation.

A very important characteristic of vegetation is its life form and is used in many vegetation classification systems (Raunkaer, 1934). Floristic characterization of a vegetation focuses on analysis and synthesis of the floristic composition of plant communities. The floristic characterization of vegetation include description of floristic composition and quantitative measurements of certain parameters of individual species. Functionally, according to Greig–Smith (1964, 1983), vegetation is an organized and an integrated whole than the individual species and possess properties which are not necessarily found in the species themselves. This shows that vegetation is a holistic system by itself and is the most obvious feature of earth's surface that forms the immediate environment of human being. During floristic analysis, whole assemblage of the constituent species are equally weighed and examined. However, most plant communities consist of so many species that it is not practical to discover all species within a community. It is common to use dominant species in naming plant communities.

Kershaw (1973) agrees that the study of floristic composition enables us to build a mental picture of an area under investigation and permit the comparison as well as the ultimate classification of different units of vegetation. Shimwell (1984) pointed out that vegetation analysis has five main objectives. The plant communities of an area, the relationship that exists within communities, how plant communities related to the environment and express their environment, how the individual plant species are distributed within these communities, and how the communities develop and function as organized living system.

Plant Community Structure

Plants are associated in communities, which have a definite structure and often a regular specific composition (Poore, 1962). The community is one of the key concepts in vegetation ecology (Poore, 1962; Braun–Blanquet, 1965). Communities may be large or small and the number of species and/or population abundance in communities may vary greatly. According to Callaway (1997), a community is the product of several ecological processes, which include competition of species to limited resources and facilitation of environment by pioneer species to other species. Plant community can also be used in the sense of describing a group of the individuals of different plant species occupying the area under study. Mueller–Dombois and Ellenberg (1974) explained plant community structure as the horizontal and vertical distribution of the abundances of plants in the community. Moreover, Larsen and Bliss (1998) refined the concept as the vertical and spatial organization of species in a community as the outcome of the processes of recruitment, growth, and competition in a physical landscape. Plant communities involve many species and environmental factors with complex relationship. Vegetation covering an area has a definite structure and composition developed because of long-term interaction with biotic and a biotic factors, and any change in the status of these factors disturbs the floristic composition of the environment. Multivariate techniques are normally employed to study the complex nature of plant communities summarizing large complex data sets obtained from community samples (Gauch and Whittaker, 1972, 1981; Gauch, 1982).

Multivariate data consist of sets of attributes or scores for each of a number of variables, this number being greater than two and sometimes large (Jeffers, 1978).

Multivariate techniques are being applied to study plant communities (Mueller–Dombois and Ellenberg, 1974). Ordination and classification are the two widely used multivariate methods used to study plant communities. These methods are essentially structuring techniques, in that both are aimed at seeking a simpler structure than that of the original raw data. In classification, sites/quadrates with species sharing certain properties are arranged in groups. Whereas in ordination, sites or species are arranged on axes, where their properties are determining by their positions (Lambert and Dale, 1964).

Cluster Analysis

Cluster analysis in this study involves grouping of plots/sites based on their similarity and difference in species they commonly share (Jeffers, 1978). Clusters could be generated using either divisive or agglomerative method (Lambert and Dale, 1964; Greig–Smith, 1983; Digby and Kempton, 1987; Jeffers, 1978). Divisive begins with dividing whole population of sites successively to produce a hierarchy in to smaller groups. Each group is being examined independently for possible further subdivision as it was extracted. Agglomerative begins with combining individual sites in a hierarchy until all individuals are eventually united in a single population. Thus, divisive method concentrate essentially on differences and start from maximal information obtained over the whole population, while agglomerative method seeks similarities and start from single units of minimal information.

Ordination

Vegetation is determined by number of environmental factors. Distribution of plant species in a particular forest as well as in certain region is also determined by number of environmental factors. Ordination is a means of analyzing the relationship between species and environmental variables aiming at description through the arrangement of samples and stands in order of similarity or difference in response to environmental gradients (Mueller–Dombois and Ellenberg, 1974). Ordination helps ecologists to understand the environmental patterns underlying vegetation composition. Ordination is used to arrange sample sites along axes based on the data on species composition. It also arranges points in such a way that sample quadrates which are located close together are similar in species composition (Goodall, 1954). In ordination, sites are arranged in small possible number of dimensions, in such a way that information available on the data is retained (Jeffers, 1978). Ordination axes are constrained to optimize their relation with a set of environmental variables. The ordination technique offers a framework within which pattern of species distribution can be correlated with a number of environmental factors there by demonstrating their relationships (Anderson, 1966).

2.8 Influence of Environmental Gradients on Plant Communities

Vegetation is not a random assemblage of individuals of species (Whittaker, 1975). Species may be found together in certain environment more frequently than would be expected by chance. Plants require limited range of or optimum environmental conditions such as light, temperature, water/moisture, nutrient, salinity, soil structure, elevation, aspect, etc in which it can survive and reproduce. These environmental conditions alter their adaptation, distribution, and assemblage. Plant species are associated in certain manner and form communities, which have a definite structure and often a regular specific composition (Poore, 1962). These plant communities exhibit various structures or recognizable patterns in spatial arrangements of their members. Smith (1990) indicated that horizontal heterogeneity in plant species results from an array of environmental influences. Plant community distribution is the manifestation of elevation, soil heterogeneity, microclimate, and disturbances (Urban *et al*., 2000). For every combination of soil, climate, altitude, slope and aspect there will be one species that grows better than any other does, so that it produces more seeds or occupies more space by vegetative spread (Crawley, 1997). Austin *et al*. (1996) also discovered that, altitude, topography, soil nutrient, moisture, and climate influence the growth and development of plants and distribution patterns of plant communities. Of these complex variables, which are difficult to separate, temperature and other climatic variables seem to be most important for describing species richness or community through the altitudinal gradient (Woodward, 1987).

Environmental parameters can be categorized in to three gradients. The first category is named as ‘indirect environmental gradients’, in which the environmental variable does not have a direct physiological influence on plant growth. It rather creates impact on correlation of other influencing environmental variables. Elevation and aspect are examples of such gradient; the secondly one is called ‘direct environmental gradients’, where the environmental factor has a physiological influence on plant growth but is not a resource for plant growth for which exploitative competition might take place. pH is an example; and the third is known as ‘resource gradients’, where the environmental variable is actually an essential resource for plant growth. Nutrients are examples.

In the same way as abiotic variables determine species distributions, biotic interactions constrain individual species ranges and, thus, the spatial variation in species assemblages (Wisz *et al.*, 2013). Thus, plant community assembly considers both the ecological interactions that shape local communities and the evolutionary and biogeographic processes that lead to variation in the diversity and its composition (Kraft and Ackerly, 2014).

2.9 Remote Sensing and Land Use /Land Cover Change

According to Sohl and Sleeter (2012), land use (LU) refers to how land is used by humans. In other words, it refers to the economic use to which land is put. Whereas land cover (LC) refers to the actual surface cover for a given location. Unlike land cover, which can be directly observed and monitored from remote sensing data, land use typically must be inferred through a combination of remote sensing observation, regional and local knowledge (including field observation), and other ancillary information that links a given land use with land cover in a region. Remote sensing data have great contributions for LU/LC modeling and is widely used to analyze landscape patterns (Sohl and Sleeter, 2012).

Remote sensing is the acquisition of information about an object or phenomenon without making physical contact to the object and thus in contrast to on site observation. In modern usage, the term remote sensing generally refers to the use of aerial sensor technologies to detect and classify objects on Earth (both on the surface, and in the atmosphere and oceans) by means of propagated signals. Typically, LU/LC is mapped from remote sensing data and then processed using appropriate software, with the help of information on current and historical landscape patterns and the driving forces behind.

According to Petit *et al*. (2001), monitoring and characterizing spatial patterns of LU/LC change are vital for understanding and predicting LU/LC change. Mertens and Lambin (1999) and Rindfuss *et al*. (2004) stated that spatial patterns of LU/LC change represent the coupled human–environment changes of an area or a landscape and is dependent on both physical and cultural factors. LU/LC modeling highly relies on both historical and current land–cover maps coupled with data representing the driving forces of change. Direct observation and mapping of land cover through remote sensing analysis are very important for identifying and quantifying the major processes of change.

As indicated by Mertens and Lambin (1999), empirical diagnostic models of LU/LC change can be developed from the site-based observations. To understand the driving forces of those observed changes, site-based observation data are used to be linked to historical and socioeconomic data. However, Parker *et al*. (2002) and Tayyebi *et al*. (2008) found that the availability of spatially and temporally consistent data representing the driving forces is a primary challenge for LU/LC modeling.

2.10 Trends of LU/LC Change in Ethiopia and its Drivers

Biophysical processes and socioeconomic drivers are among the major factors contributing for LU/LC changes occurring over time and space dimensions (FAO, 2006). Over the past century, agricultural lands have doubled worldwide (Etter *et al*., 2006). In Sub–Sahara Africa, high population growth contributed for overexploitation of natural resources. In these areas productivity of land is low, and the extent and rate of LU/LC change is high (Bassett and Bi Zueli, 2000). These LU/LC changes have implications for changes in land management practices in the landscape, hydrological cycles, biodiversity, microclimates, and ground water (Lambin and Geist, 2003).

Forests are the major natural resources that are greatly affected by the LU/LC changes, and are converted to agricultural lands.

According to Tsehaye Gebrelibanos and Mohammed Assen (2015), regional and local landscapes of the country have been changing because of human–induced LU/LC changes. Studies conducted by Gete Zeleke (2000), Kebrom Tekle and Hedlund (2000), Gete Zeleke and Hurni (2001), Fikir Alemayehu *et al*. (2009), and Mohammed Assen (2011) showed that, high rate of LU/LC has been experienced in many parts of Ethiopian highlands. Agriculture and settlement has increased in the expense of forest resources. Despite the fact that the rate, extent, and consequences of forest loss have been documented in Ethiopia by EFAP (1994) and FAO (2010), relationships between demographic, economic, and institutional factors that cause LU/LC changes at local level are not well documented.

Studies by Woldeamlak Bewket and Sterk (2005) in Chemoga showed that, decrease in vegetative cover at the watershed area resulted in generation of high surface runoff in rainy seasons. The same study further explained that, the stream flow of the watershed was affected by shortage of rainfall, and degradation of the watershed because of LU/LC changes.

According to Woldeamlak Bewket and Ermiyas Teferi (2009), soil erosion caused due to LU/LC, is a major contributor to the prevailing food insecurity in the country by removing the fertile soil, as a result the area became degraded. Unsustainable exploitation of the land resource, manifested by extensive removal of vegetation for fuelwood, expansion of cultivation and grazing in steep land areas are the underlying cause for the excessive rate of soil loss and food insecurity (Gete Zeleke, 2000;

Kebrom Tekle and Hedlund, 2000; Weldeamlak Bewket, 2002; Aklilu Amsalu *et al*., 2007).

Underlying causes and associated consequences of LU/LC changes are explained in terms of major events such as socio–ecological, environmental, policy and development intervention (Teshome Abate and Ayana Angassa, 2016). Climate change–related events (such as rainfall variability, recurrent drought, and temperature), development intervention related events (i.e., promotion of crop production, construction of water point), policy related events (i.e., ban of fire, promotion of crop production, settlement) are influencing the LU/LC changes.

Climate change is affecting LU/LC and vegetation changes within individual landscapes directly or indirectly. Bloesch (1999) suggested that, climate change is affecting all types of land use and ecosystem services, as well as the behavior of humans. Demographic factors related to population growth are the major among the underlying causes for LU/LC changes in the country (Diress Tsegaye *et al*., 2010). Population pressure together with other anthropogenic factors has significantly contributed to the changes in LU/LC through expansion of cultivation, settlements, and intensive exploitation of existing forest resources. Government policies on forest management and use–right, expansion of cropland and settlement were also reported to be the main causes for LU/LC changes. In addition, both natural and manmade fire were affecting vegetation in various parts of the country, and regulating the normal functioning of rangeland ecosystems (Bloesch, 1999; Laris, 2002; Angassa and Oba, 2008; and Diress Tsegaye *et al*., 2010).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Description of Study Areas

This study was carried out at the Afromontane forests of Tiro Boter Becho (TBB) state forest and Chebera Churchura National Park (CCNP).

3.1.1 Tiro Boter Becho

The first study site, TBB (Figure 1) is located between Tiro Afeta and Chora Boter Weredas of Jimma Zone, Oromia Regional State. It is situated between $08^{0}01'$ – $08^{0}28'$ N latitude and $037^{0}09'$ – $037^{0}20'$ E longitude, covering an area of 40,528ha. TBB lies along a volcanic mountain ridge, running almost north to south, and rising to a series of small peaks of 3030 m.a.s.l. It is possible to reach to the forest in two ways. One is through Boter Becho, which is located at about 73 km southwest of Welkite town, which in turn is 150km from Addis Ababa. The other route is through Tiro, which is located at about 55 km northwest of Asendabo town, which in turn is 300 km from Addis Ababa. There are several streams flowing out of the Afromontane forest of TBB to Gilgel Gibe, which forms a wide valley supporting the lower parts of the forest.

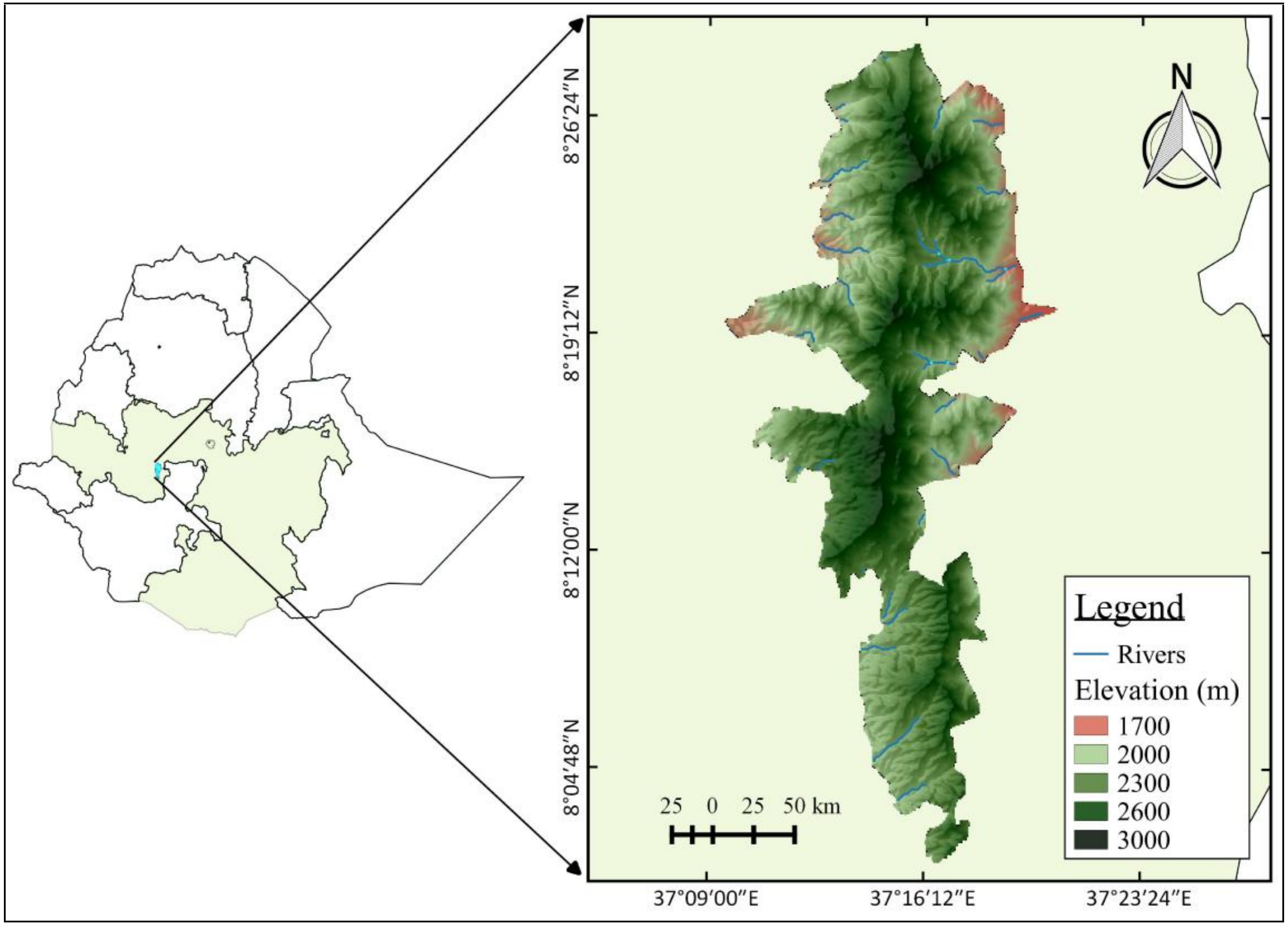

Figure 1. Map of Ethiopia, Oromiya Regional State, and the study area (TBB)

Temperature and Rainfall

According to the rainfall data obtained from National Meteorological Agency for the period 2001 – 2015, the mean annual temperature of Boter Becho is about 14.3 ^{o}C with maximum (26.6 ^{o}C) from January to March and minimum (1.0 ^{o}C) from November to December. The mean annual rainfall is 1434 mm year^{-1}, with high variation from year to year, ranging from about 1088 – 1703 mm year^{-1} (SD = 182.94). The rainfall pattern is unimodal, with a dry season from November to February and then gradually increasing to the rainy season from March to October. July is the month where the area gets the highest rainfall (Figure 2).

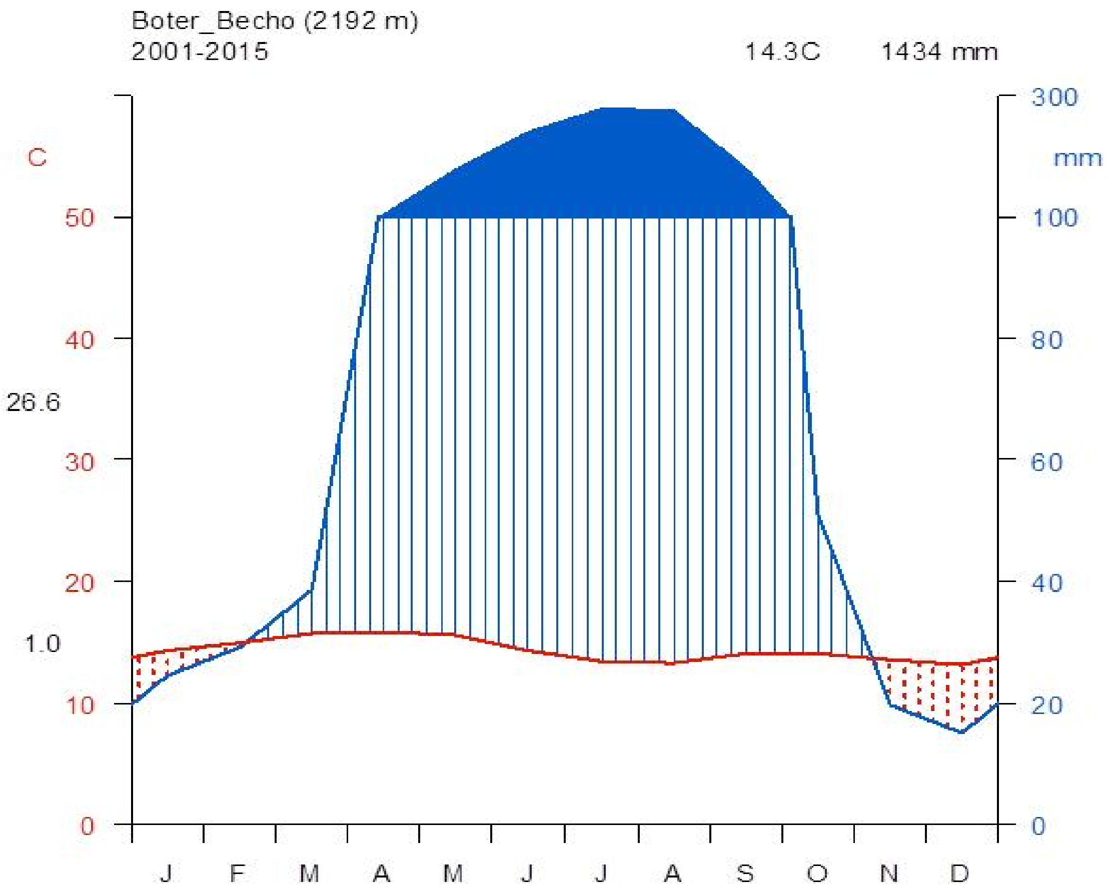

Figure 2. Climadiagram for Boter Becho Station (Data source: NMA)

Topography and Soil

The landform changes from flat surface on top of plateau to very steep slopes and valley bottoms. The altitude of the area ranges from 1650 to 3030 m.a.s.l. The soils in TBB where the Afromontane forest exists are acidic with pH value ranging between pH of 3.94 and 6.43 (own data). According to the soil classification system by FAO/UNESCO (1990), the soil association of TBB is Eutric Nitosols.

Vegetation

TBB forest is composed of Moist Afromontane forest (Figure 3) at higher altitude and *Combretum–Terminalia* woodland in its lower altitude. The montane forest characteristically contains a mixture of *Podocarpus falcatus* and broad–leaved species as emergent trees in the canopy including *Pouteria adolfi–friederici*. There are also a number of medium–sized trees, and large shrubs. In addition, *Juniperus procera, Hagenia abyssinica* and other small trees that grade into an open *Erica arborea* zone around 2900 m are also present. There are some patches of *Arundinaria alpina* in wet, sheltered valleys.

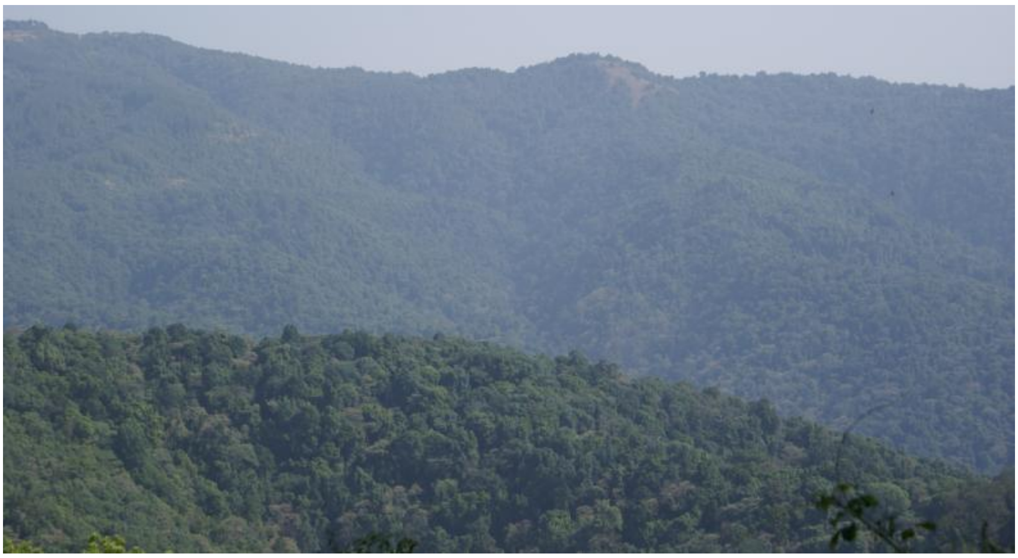

Figure 3. Partial view of Moist Afromontane forest of TBB (own photo)

3.1.2 Chebera Churchura National Park

The second study site is the Afromontane forest of Chebera Churchura National Park (CCNP). CCNP is one of the recently established parks in the Southern Nations Nationalities and Peoples Regional State (SSNPRS), with the primary objective of protecting wildlife (especially the African Elephants and Buffaloes). The park lies within the western side of the central Gibe–Omo Basin, between Dawro Administrative Zone and Konta Special Woreda, situated between $06^0 40'$ – $07^0 09'$ N latitude and $036^0 30'$ – $036^0 58'$ E longitude, covering an area of 121 km^2 (Figure 4). The park is located at about 580 km southwest of Addis Ababa. In addition to existing wildlife resource, the park is also known by its small crater lakes and major rivers. There are also several hot springs and waterfalls in the park. Omo River is bordering the park to the South, to which all the major rivers from the park are draining.

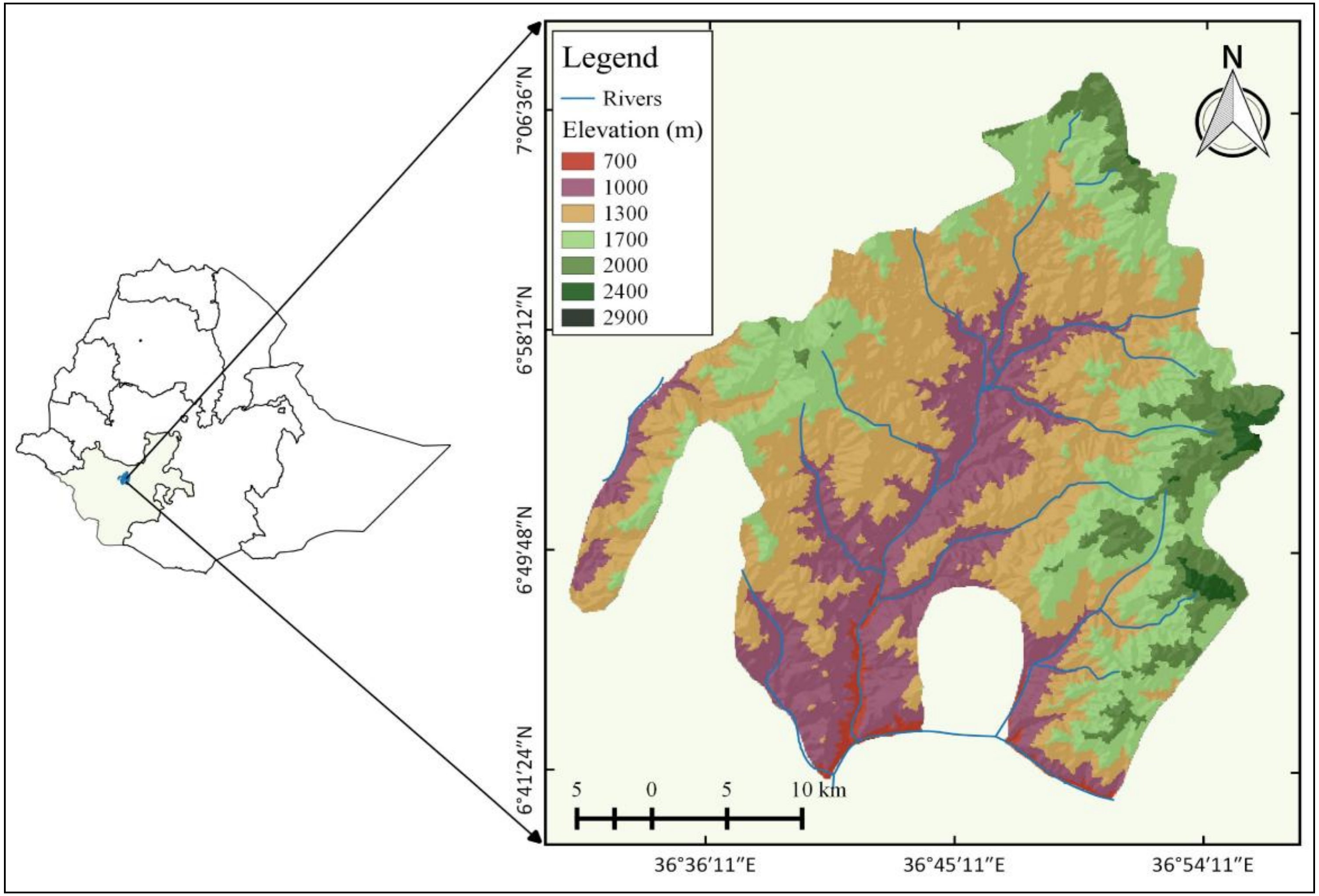

Figure 4. Map of Ethiopia, SNNPRS, and the study area (CCNP)

Temperature and Rainfall

The rainfall data obtained from NMA for the period 2005 – 2013 shows that the mean annual temperature at Ameya, the nearest town to CCNP (21 km air distance), is about 18.1 °C with maximum (25.1 °C) from December to April and minimum (12.1 °C) from June to October. The mean annual rainfall is 2082 mm year^{-1}, with high variation from year to year, ranging from about 1810–2375 mm year^{-1} (SD = 198.69). The rainfall pattern is bimodal, with a dry season from December to February and then gradually increasing to the rainy seasons between March and November. July is the month, where the area gets the highest rainfall (Figure 5).

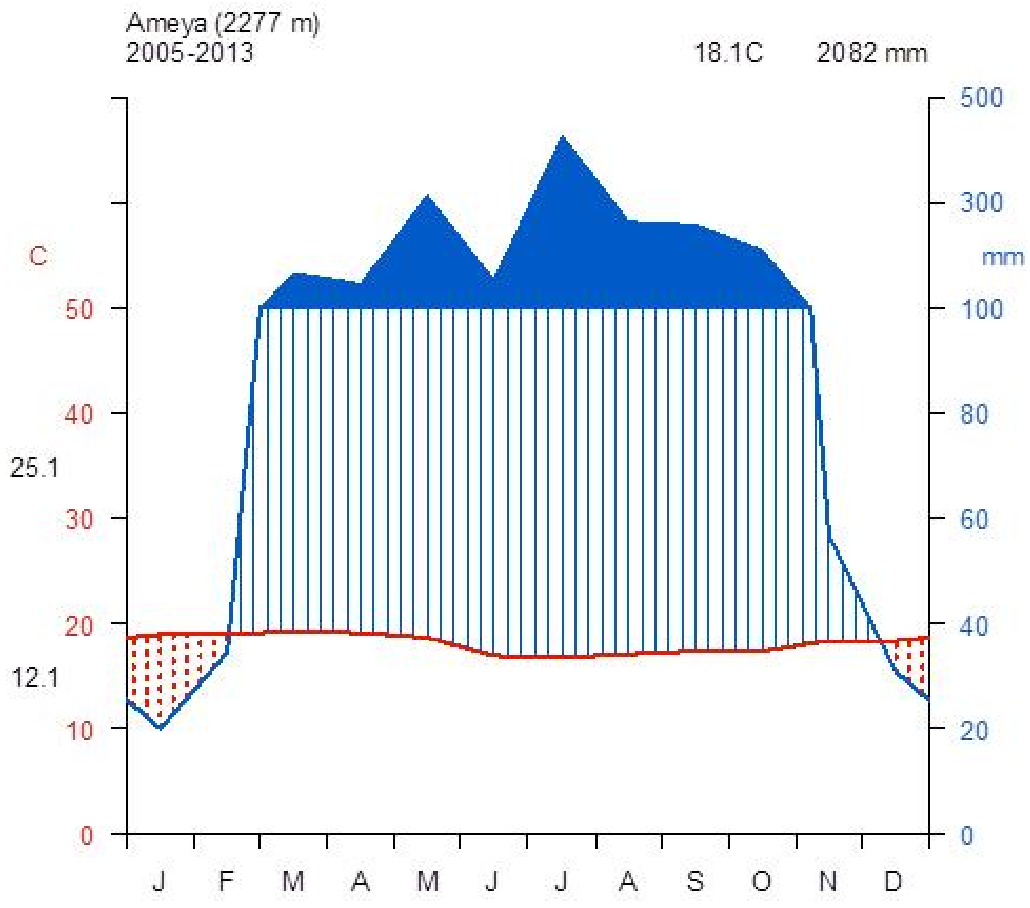

Figure 5. Climadiagram for Ameya Station (Data source: NMA)

Topography and soil

The park is characterized by its undulating heterogeneous hilly terrain with various sized valleys and gorges. The altitude of the park ranges from 550 to 2800 m.a.s.l. The soils of CCNP, where the Afromontane forest is situated, are slightly acidic with pH value ranging between pH of 5.32 and 6.36 (own data). According to the soil classification system by FAO/UNESCO (1990), the largest portion of the park consists of Eutric Cambisols and small portion of the northern and western part of the park has a soil type of Eutric Nitosols.

Vegetation

There are different vegetations types in Chebera Churchura National Park: Moist Afromontane Rainforest (Figure 6), Riverine vegetation, *Combretum–Terminalia* woodland and Wooded Grassland.

Figure 6. Partial view of Moist Afromontane forest of CCNP (own Photo)

The largest portion of the park is grassland with scattered trees, where grass reach up to 3 m tall. Fire is taking place every year in the park during the dry season in the lowland areas occupied by grasses. Some broad–leaved emergent trees species in the canopy include *Pouteria adolfi–friederici* and *Polyscias fulva*. There are also a number of medium–sized trees and shrubs at the Afromontane forests of the area.

3.2 Preliminary Survey

Reconnaissance survey was carried out to both TBB and CCNP prior to data collection. This overview was important for the selection of the representative sites for data collection.

3.3 Methods of Data collection

3.3.1 Vegetation Sampling

Transects were laid along gradients in the Afromontane part of TBB and CCNP for the collection of vegetation and environmental data following Muller–Dombois and Ellenberg (1974) and Kent and Coker (1992). Vegetation data were collected in each sampling sites using plot area of 30 m x 30 m (900 m^2). Because of high canopy closure, the herbaceous cover in the area was sparse. Therefore, within each main plot a 5 m x 5 m sub–plot was used for recording herbaceous species. A total of 118 and 61 plots were taken from the Afromontane forests of TBB and CCNP respectively, depending on the size of the Afromontane forests of the areas. The plots were established at 300 m along line transects. 32 and 14 transects were laid in TBB and CCNP respectively. Transects were spread at 500 m from one another.

Each of the vascular plant species encountered in each plot of the Afromontane forests TBB and CCNP were recorded. Height measurements were taken for each woody plant with height ≥ 2 m and diameter measurements were taken for each woody plant with DBH ≥ 2.5 cm. Plants with a height of less than 2 m and DBH less than 2.5 cm were treated as seedlings and saplings respectively. Moreover, percentage of canopy cover of each plant species in the sampling plots was visually estimated. Species occurring outside the plots were also recorded for enriching the diversity of the flora of the study area. Voucher specimens were collected, pressed, and brought to the National Herbarium (ETH), Addis Ababa University, for identification using published volumes of Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989; Hedberg and Edwards, 1995; Edwards *et al*., 1995; Edwards *et al*., 1997; Edwards *et al*., 2000; Hedberg *et al.,* 2003; Hedberg *et al.,* 2004; Hedberg *et al.,* 2006; and Hedberg *et al.,* 2009), other taxonomic works and comparing them with specimens already deposited in the National Herbarium.

3.3.2 Environmental Data

Geographic coordinate and elevation for each main plot was recorded using Garmin Global Positioning System (GPS). Slope of each main plot was taken using Sunto Clinometer. In addition, soil samples were collected from each main plot from the depth of 0–10 cm, 10–20 cm and 20–50 cm at four corners of the main plot and composite samples were made for each layer.

Disturbance on the forest resources were estimated and rated as "Low (when the number of seedlings trampled in a sampling plot were less than 10 and no trees cut down)", "Medium (when the number of seedlings trampled in a sampling plot were between 10 and 20, and/or one tree is cut down)", and/or "High (when the number of seedlings trampled in a sampling plot were higher than 20, and/or more than one trees are cut down)" based on number of seedling trampled, footpaths, and extent of grazing.

3.3.3 Land Use Land Cover Data

Landsat images of the three selected years within the past thirty years (Table 1) were obtained from United States Geological Survey (USGS) (an open source) are used to analyze the land use/land cover in the study areas.

Table 1. Description of Landsat Images used and their Sources

No	**Image**	**Sensor**	**Resolution or scale**	**Year of image acquisition**	**Source**
1	Landsat 8	Operational Land Imager (OLI)	30m	2015	USGS
2	Landsat 7	Enhanced Thematic Mapper Plus (ETM+)	30m	2000	USGS
3	Landsat 5	Thematic Mapper (TM)	30m	1984	USGS

Field observations and GPS ground truthing points were taken from the actual field, and assisted with Google Earth and topographic maps of 1972 of the area for the purpose of land cover classification. Data regarding the major driving forces of the LU/LC changes and threats on the vegetation in the study area were collected using focus group discussions, and interview with key informants from local people residing near the forests. Two focus group discussions were carried out at each study site. Each focus group had fifteen individuals composed of elders, youths, and administrative officials. Key informants, who lived in the area for more than thirty years were selected purposefully.

During the key informant interviews and focus group discussions, issues regarding the main economic activity/activities practiced in this area, land ownership and agricultural practice of local communities, the benefit(s) that the local communities are obtaining from the natural forest in the area in a rank order, the main source(s) of energy for your household, source of wood/timber for community's for firewood and house construction, trends of population change, trends of change of natural forest and agricultural lands in the area, factors contributing to changes to forest and agricultural lands, and suggested forest management approaches were raised.

3.4 Data Analysis

3.4.1 Plant Diversity analysis

According to Whittaker (1975), the description of vegetation involves the analysis of species diversity, evenness, and similarity. Shannon and Wiener (1949) index of diversity analysis, was applied to quantify the species diversity and evenness of the Afromontane forests of TBB and CCNP.

The diversity was calculated as: $\mathrm{H}' = -\sum_{\mathrm{i}=1}^{\mathrm{s}} \mathrm{pi} \ln \mathrm{pi}$ $H' = -\sum_{i=1}^{s} pi \ln pi$,

Where: Pi= the proportion of individuals or the abundance of i^{th} species as a proportion of total cover in the sample.

Evenness was calculated using the formula: $J = \frac{H'}{\ln(S)}$,

Where: J = evenness; H' = Shannon–Wiener diversity index; and S = total number of species in the sample.

The value of evenness index falls between zero and one. The higher the value of evenness index the more evenly distributed the species are within the given area (Kent and Coker, 1992).

Floristic Similarity

The floristic similarity of the two forests under study and other similar forest in the country was assessed in terms of species composition using the Sorensen's coefficient of similarity (Ss) shown in Kent and Coker (1992). Sorensen's coefficient of similarity value ranges from zero (complete dissimilarity) to one (total similarity).

Floristic similarity of forests was calculated using the formula: $Ss = \frac{2a}{(2a+b+c)}$,

Where: Ss = Sorenson Similarity coefficient; a = the number of species common to both forests compared; b = the number of species in one of the forest to be compared; and c = the number of species in present in other forest.

Density

The density of woody species at the Afromontane forests of TBB and CCNP was computed in stems per hectare ($stems.ha^{-1}$) basis. The density of individuals with DBH > 10 cm and DBH > 20 cm was computed and the ratio of these two was taken as a measure of the proportion of small– and large–sized individuals (Grubb *et al*. 1963).

3.4.2 Vegetation and Plant Community Structural Analysis

The percentage cover values for trees, shrubs, herbs and grasses estimated in each sample plots was converted into cover abundance values using 1 - 9 modified Braun-Blanquet scale (Table 2) as modified by van der Maarel (1979).

Table 2. Modified Braun-Blanquet scale for cover abundance values

Scale	Cover abundance values
1	Rare, generally one individual
2	Occasional, less than 5 % cover of the total
3	Abundant, with less than 5% cover of the total
4	Very abundant, with less than 5% cover of the total
5	Cover 5-12.5% of the total area
6	Cover 12.5- 25% of the total area
7	Cover 25-50% of the total area
8	Cover 50-75% of the total area
9	Cover >75% of the total area

Source: van der Maarel, 1979

Plots were further grouped into clusters with the aid of Multivariate methods using R (Zerihun Woldu, in press). Using similarity Ratio as resemblance index and Wards method of amalgamation technique.

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

The dissimilarities between the clusters are the squared Euclidean distances between cluster means. The vertical axis of the dendrogram represents the dissimilarity or distance between clusters. The horizontal axis represents the main plots and clusters. Each joining (fusion) of two clusters is represented on the graph by the splitting of a vertical line into two vertical lines. The vertical position of the split, shown by the short horizontal bar, gives the dissimilarity (distance) between the two clusters.

The communities distinguished were further refined in an indicator species table. Indicator species is a species that characterizes of a cluster of samples. Indicator Value of each species was calculates as the product of its relative frequency and its relative abundance. Indicator values range from 0 to1. The significance of indicator values were tested through permutation test. Relationship of plant communities and environmental variables was presented in a multivariate method that expresses relationships between samples, species and environmental variables in a low–dimensional space called ordination diagrams (McCune and Grace, 2002). For this study, constrained RDA (Redundancy analysis) is used instead of CCA (the most popular ordination methods in community ecology when the length of the axis of DCA is shorter then 3SD) (ter Braak & Šmilauer, 2002; Lepš & Šmilauer, 2003). All environmental variables were subjected to ANOVA and Adonis test prior to DCA for their significance at P=0.05.

Regarding the structure of the Afromontane forests of the study areas, analyses were carried out in terms of tree density, girth diameter, height, and basal area in hectare basis. The diameter at breast height (DBH) was grouped into eleven diameter classes and the percentage distributions of woody species in each class were computed to indicate plant population structure of the area. Tree height was also grouped into seven height-classes and the percentage distributions of woody species in each height-class were calculated. Structural comparison of the two Afromontane forests under investigation to other forests in Ethiopia was carried out.

Basal Area

According to Barbour *et al*. (1987), basal area (BA) is the cross–sectional area of tree stems at breast height. And it is a measure of dominance, where the term dominance refers to the degree of coverage of species as an expression of the space it occupies.

Basal Area was calculated as: $BA = \frac{\pi d^2}{4}$, Where: BA= basal area in m^2 per hectare; d = diameter of tree stem at breast height; and π = 3.14.

Importance value Index (IVI)

The ecological significance of a species in a forest was compared using Importance Value (IV) of a species (Lamprecht, 1989). Important values Index (IVI) of woody species (Mueller–Dombois and Ellenberg 1974) was computed by summing up their relative density (RD), relative dominance (RDO) and relative frequency (RF). *i.e*. IVI = RD+RDO+RF, Where,

$$\text{Relative density} = \left[\frac{\text{The number of individuals of a species}}{\text{The total number of all individuals}}\right] \text{X } 100;$$

$$\text{Relative frequency} = \left[\frac{\text{The number of plots where a species occur}}{\text{The total plots used during the study}}\right] \text{X } 100; \text{ and}$$

$$\text{Relative dominance} = \left[\frac{\text{Dominance of a species}}{\text{Dominance of all species in the study area}}\right] \text{X } 100$$

Dominance: area a species occupies in a stand (or basal area for trees) on a unit area basis

$$\text{Dominance (Do)} = \left[\frac{\text{Basal area of individual species in the sample (m}^2\text{)}}{\text{Total area of the sample (m}^2\text{)}}\right]$$

or

Dominance = mean basal area of a species multiplied by number of trees of a species per hectare.

Frequency (F) was calculated as the number of plots in which a species recorded divided by total plots

In order to describe the effects of environment on the distribution of plant species, pH, organic matter, Cation Exchange Capacity (CEC), total Nitrogen, available Phosphorus and soil textures only were analyzed from composite soil samples collected from each layer of the main plot.

Vertical Structure of the Forest

The vertical structures of woody species in the two Afromontane forests under study were described following the IUFRO (International Union for Forestry Research Organization) classification scheme (Lamprecht, 1989). Three vertical structures were distinguished as: upper storey (tree height higher than 2/3 of highest height), middle storey (tree height between 1/3 and 2/3 of highest height) and lower storey (tree height lower than 1/3 of the highest height).

3.4.3 LU/LC Detection and Analysis

LU/LC of the study area were monitored by analyzing the satellite imageries at a resolution of 30 m from the year 1984, 2000, and 2015. The boundary of the study area was obtained from the CCNP Head Quarter and Oromia Forest and Wildlife Enterprise (OFWE), TBB District Office.

Landsat image processing, spatial analysis, and change detection were carried out using Quantum Geographic Information System QGIS (Lyon–version 2.12.3). Automatic Classification Plug-in (Congedo *et al.*, 2013) was used for image processing and LU/LC classification and analysis. In addition, Microsoft Office Excel was used to create charts and graphs. Supervised digital image classification technique was employed using spectral angle mapping algorithm and complemented with 25 ground points from each LU/LC types. The images were projected, to the spatial reference coordinate systems of Adindan / UTM zone 37N, prior to image processing and classification. The sub-setting of satellite images were performed for extracting study area from both images by taking geo-referenced outline boundary of the study area map as AOI (Area of Interest). For better classification results, normalized difference vegetation index (NDVI) was created to classify the Landsat images.

Three LU/LC maps corresponding to the three reference years were finally produced based on reflectance characteristics and color features of the various LU/LC types. The trends and extents of each LU/LC change were determined for the respective years of the study. Field visit and focus group discussions were carried out to obtain additional information on the long year practice regarding the LU/LC changes in the study areas. Descriptions to land use classes obtained from classification of Landsat images through the methodology described in Congedo *et al*., (2013) are given in Table 3.

Table 3. Description of LU Classes Identified

LU Class	Description
Forest	Areas covered mainly with natural forest and plantations, whose pixels had higher NDVI values (between 0.61 – 1.00)
Woodland	Areas covered with woodland and sparse vegetation, whose pixels had medium NDVI values (between 0.41 – 0.60)
Shrub/Bushland	Areas covered with shrub/bushes, whose pixels had NDVI values between 0.31 – 0.40
Grassland	Areas covered with open grasses and bushes used for grazing (pixels had NDVI values between 0.21 – 0.30)
Agriculture and Settlement	Plain and slightly undulating landscapes that are cultivated; land surface features devoid of any type of vegetation cover including settlement areas, abandoned land, roads, gullies and waterways (pixels with NDVI value between 0.10 – 0.20)
Water body	Surface water such as lakes and flood plains covered with water (pixels with NDVI value less than or equal to 0.1)

LU/LC change for 1984 to 2000, 2000 to 2015, and 1984 to 2015 were analyzed using transformation matrices from the three LU/LC maps of the study area with an overlay analysis technique.

The extent of LU/LC change at TBB and CCNP are given in matrix. The change detection was carried out using images of LU/LC analysis from two different years and reported in hectare. The land use land cover change matrix depicts LU/LC classes, LU/LC classes remain unchanged, and direction of changes of the LU/LC classes.

Classification accuracy

Classification accuracy of LU/LC classification is presented using matrix known as confusion matrix. LU/LC classification is usually carried out using the reference and classified data. The classified data represent the location of the spectrally classified pixel in the classified image. Whereas, the reference data denote the actual location of the pixel on the ground, which is obtained from the ground truthing. The matrix presents the numbers of correctly classified and misclassified pixels of a classified image. The total numbers of pixels that exactly match both the reference and classified data in the cell array are the correct classifications, and are shown in bold diagonally in error matrices. The overall classification accuracy shows that how accurate the classification was. It is provided as the ratio of the sum of correct classifications and total randomly generated reference pixels used for the assessment.

Kappa value of classification accounts for the off–diagonal elements as a product of the row and column marginal and not just the diagonal values in the estimation of accuracy. Kappa coefficient is used to determine if the accuracy presented in the error matrix is significantly better than a random result. It also accounts for the random accuracy of a given classification.

Kappa (K) is calculated using the formula: $K = \frac{N \sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} (X_{i+} * X_{+i})}{N^2 - \sum_{i=1}^{r} (X_{i+} * X_{+i})}$,

Where, r = number of rows in the error matrix; X_{ii} = number of observations in row i and column i (on the major diagonal); X_{i+} = total of observations in row i (shown as marginal total to right of the matrix); X_{+i} = total of observations in column i (shown as marginal total at bottom of the matrix); and N = total number of observations included in matrix

Kappa value ranges from zero to one. Kappa of one indicates perfect match between the reference and classified data and zero indicates that any match is totally due to chance.

Rate of land use and land cover changes in the study area

The rate of LU/LC change (RC) in ha.year^{-1} basis was calculated using the formula:

$$RC = \frac{(A - B)}{t},$$

Where: RC = rate of LU/LC change; A = recent area of LU/LC in ha; B = previous area of LU/LC in ha; and t = time interval between A and B in year

Overall steps followed for LU/LC study is presented in the flowchart (Figure 7).

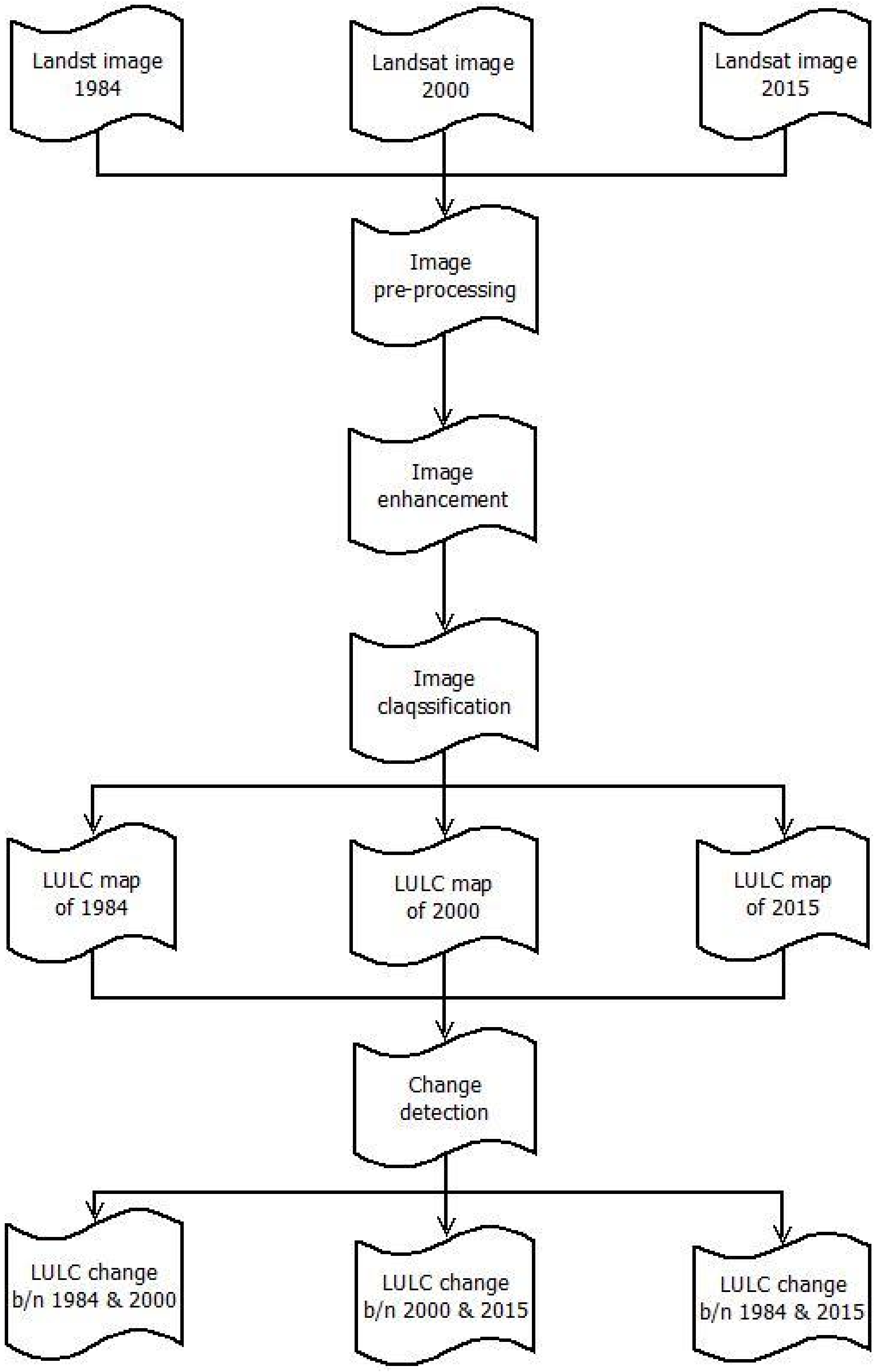

Figure 7. Flowchart showing the steps followed during LU/LC evaluation (own sketch)

CHAPTER FOUR

4. RESULTS

4.1 Plant Diversity and Species Composition of Afromontane forest of TBB and CCNP

Two hundred and four plant species belonging to 168 genera, and 72 families were recorded from sample plots and their vicinity at the Afromontane forest of TBB. Whereas one hundred and forty four plant species belonging to 131 genera and 66 families were recorded from sample plots and their vicinity at the Afromontane forest of CCNP. The complete list of plant species identified in the two study areas is given in Annex 1.

Plant species identified from the study areas were grouped based on their habit according to plant habit classification of the Flora books (Table 4 and Table 5).

Table 4. Distribution of species according to growth–form/habit of plants at the Afromontane forest of TBB with their corresponding number species

Habit	Number of Species	Percent (%)
Tree/Shrub	55	27.0
Herb	58	28.4
Tree	28	13.7
Shrub	31	15.2
Liana (Woody climber)	17	8.3
Herbaceous climber	6	2.9
Fern	5	2.5
Grass	4	2.0

Table 5. Distribution of species according to growth–form/habit of plants at the Afromontane forest of CCNP with their corresponding number species

Habit	Number of Species	Percent (%)
Tree/Shrub	43	29.9
Herb	39	27.1
Tree	26	18.1
Shrub	12	8.3
Liana (Woody climber)	15	10.4
Herbaceous climber	5	3.5
Fern	3	2.1
Grass	1	0.7

From total families identified at the Afromontane forest of TBB and CCNP (Annex and Annex 3 respectively), the top five families with regard to their species composition are provided in Table 6 and Table 7 respectively, in descending order. In TBB, family Asteraceae has the highest number of species, followed by family Acanthaceae. Whereas In CCNP, family Fabaceae has the highest number of species followed by family Acanthaceae and Asteraceae.

Table 6. List of top five plant families with their number of genera and species encountered at the Afromontane forest of TBB

Family	No. of Species	%	No. of Genera	%
Asteraceae	19	9.3	15	9.0
Acanthaceae	12	5.9	9	5.4
Fabaceae	11	5.4	9	5.4
Lamiaceae	11	5.4	9	5.4
Rubiaceae	9	4.4	8	4.8

Table 7. List of top five plant families with their number of genera and species encountered at the Afromontane forest of CCNP

Family	No. of Species	%	No. of Genera	%
Fabaceae	8	5.56	7	5.51
Acanthaceae	7	4.86	6	4.72
Asteraceae	7	4.86	7	5.51
Euphorbiaceae	6	4.17	6	4.72
Rubiaceae	6	4.17	6	4.72

The Shannon diversity index of Afromontane forest of TBB was 3.45 and CCNP was 3.32 with their evenness value of 0.80 and 0.84 respectively. Based on the information available on the published books of Flora of Ethiopia and Eritrea, 12 endemic plant species were recorded from the Afromontane forest of TBB and 6 endemic plant species from the Afromontane forest of CCNP (Table 8).

Table 8. Endemic species and their habit at the Afromontane forests of TBB and CCNP

Scientific Name	Family	Habit	Occurrence
Acanthus sennii Chiov.	Acanthaceae	Sh	TBB
Cissampelos pareira L.	Menispermaceae	Li	TBB
Clematis longicauda Steud.ex A. Rich.	Ranunculaceae	Cl	CCNP and TBB
Erythrina brucei Schweinf.	Fabaceae	T	CCNP and TBB
Lippia adoensis Hochst. ex Walp.	Verbenaceae	Sh	TBB
Maytenus addat (Loes.) Sebsebe	Celastraceae	T	TBB
Millettia ferruginea (Hochst.) Bak. subsp. *darassana* (Cuf.) Gillett	Fabaceae	T	CCNP and TBB
Pittosporum viridiflorum Sims.	Pittosporaceae	T/Sh	CCNP and TBB
Plectocephalus varians (A. Rich.) C. Jeffrey ex Cufod.	Asteraceae	H	TBB
Solanecio gigas (Vatke) C. Jeffrey	Asteraceae	T/Sh	TBB
Tiliachora troupinii Cufod.	Menispermaceae	Li	CCNP and TBB
Vepris dainellii (Pichi–serm.) Kokwaro	Rutaceae	T/Sh	CCNP and TBB

4.2 Vegetation Structure

4.2.1 Plant Community Structure of the Afromontane forest of TBB and CCNP

4.2.1.1 Cluster Analysis

Result from the cluster analysis shows that the plant species recorded from one hundred eighteen plots of the Afromontane forest at TBB were clustered in to five plant communities (Figure 8).

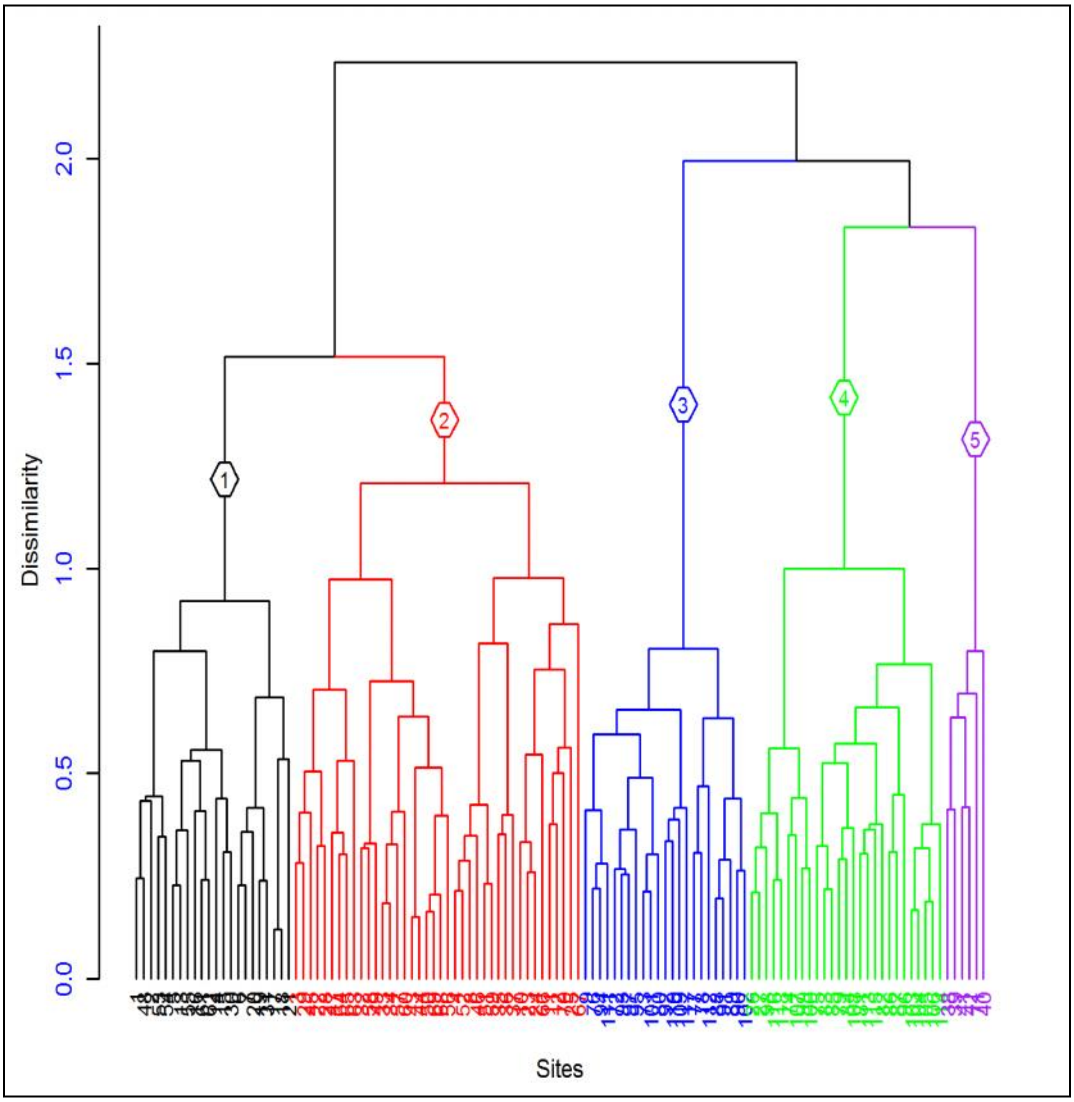

Figure 8. Dendrogram showing clusters of plots obtained from the Afromontane forest of TBB

Cluster numbers in the dendrogram corresponds to the communities in the subsequent discussion. These clusters were designated as local plant communities and given names after two indicator species with higher species indicator value (Annex 4).

Community 1: *Apodytes dimidiata - Podocarpus falcatus* community

This plant community was distributed at altitudes between 2335 and 2685 m.a.s.l. with mean altitude of 2488 m.a.s.l. This community is dominated by *Podocarpus falcatus* and *Apodytes dimidiata* (Figure 9). Grazing and tree cutting is common in this community.

Figure 9. Partial view of *Podocarpus falcatus* dominated Afromontane forest of TBB (own photo)

Species in upper storey in this community include *Syzygium guineense* subsp. *afromontanum*, *Olea capensis* subsp. *macrocarpa*, *Podocarpus falcatus*, and *Prunus africana*. Species in middle storey in this community include *Apodytes dimidiata*, *Chionanthus mildbraedii*, *Bersama abyssinica*, *Olinia rochetiana*, *Ficus sur*, *Allophylus abyssinicus*, *Ilex mitis* and *Polyscias fulva*. Species in lower storey include *Psychotria orophila*, *Oxyanthus speciosus*, *Maytenus gracilipes* subsp. *arguta*, *Vepris dainellii*. Understory species in this community includes *Oplismenus hirtellus*, *Setaria megaphylla*, *Acanthopale pubescens* and *Acanthus eminens*.

Community 2: *Croton macrostachyus - Pouteria adolfi-friederici* community

This community was distributed at altitudes between 2105 and 2550 m.a.s.l. with mean altitude of 2341 m.a.s.l. This community is distant from settlement areas disturbance resulting from human and grazing in this community is very unlikely compared to other communities. This area is known by its high density of emergent tree species of *Pouteria adolfi-friedrici, Croton macrostachyus* and *Prunus africanus* (Figure 10).

Figure 10. Partial view of *Pouteria adolfi-friedrici* dominated Afromontane forest of TBB (own photo)

Species in upper storey in this community include *Olea capensis* subsp. *macrocarpa*, *Syzygium guineense* subsp. *afromontanum*, *Prunus africana*, *Podocarpus falcatus*, *Croton macrostachyus* and *Pouteria adolfi–friederici*. Species in middle storey in this community include *Macaranga capensis*, *Celtis africana*, *Olinia rochetiana*, *Polyscias fulva*, *Ficus sur*, *Allophylus abyssinicus*, *Apodytes dimidiata* and *Millettia ferruginea* subsp. *darassana*. Species in lower storey include *Bersama abyssinica*, *Vepris dainellii*, *Psychotria orophila* and *Chionanthus mildbraedii*. Understory species in this community includes *Oplismenus hirtellus*, *Acanthus eminens*, *Acanthopale pubescens* and *Setaria megaphylla*.

Community 3: *Macaranga capensis - Lepidotrichilia volkensii* community

This community was distributed at altitudes between 2165 and 2616 m.a.s.l. with mean altitude of 2261 m.a.s.l. Species in upper storey in this community include *Olea capensis* subsp. *macrocarpa*, *Syzygium guineense* subsp. *afromontanum*, *Podocarpus falcatus*, *Pouteria adolfi–friederici* and *Prunus africana*. Species in middle storey in this community include *Olinia rochetiana*, *Millettia ferruginea* subsp. *darassana*, *Albizia gummifera*, *Schefflera abyssinica*, *Celtis africana*, *Ilex mitis*, *Polyscias fulva*, *Allophylus abyssinicus* and *Schefflera volkensii*. Species in lower storey include *Dracaena afromontana*, *Ehretia cymosa*, *Chionanthus mildbraedii*, *Bersama abyssinica*, *Psychotria orophila*, *Oxyanthus speciosus*, *Vepris dainellii*, *Teclea nobilis*, *Pittosporum viridiflorum*, *Clausena anisata*, *Canthium oligocarpum* and *Rytigynia neglecta*. Understory species in this community includes *Acanthus eminens*, *Oplismenus hirtellus*, *Acanthopale pubescens* and *Setaria megaphylla*.

Community 4: *Clausena anisata - Pittosporum viridiflorum* community

This community was distributed at altitudes between 2141 and 2585 m.a.s.l. with mean altitude of 2307 m.a.s.l. Species in upper storey in this community include *Olea capensis* subsp. *macrocarpa*, *Syzygium guineense s*ubsp. *afromontanum*, *Podocarpus falcatus* and *Pouteria adolfi–friederici*. Species in middle storey in this community include *Macaranga capensis*, *Olinia rochetiana*, *Ilex mitis*, *Millettia ferruginea* subsp. *darassana, Ficus sur*, *Allophylus abyssinicus, Schefflera abyssinica* and *Lepidotrichilia volkensii*. Species in lower storey include *Dracaena afromontana, Psychotria orophila, Maytenus gracilipes* subsp. *arguta* and *Oxyanthus speciosus*. Understory species in this community includes *Setaria megaphylla*, *Oplismenus hirtellus*, *Acanthus eminens* and *Desmodium repandum.*

Community 5: *Myrsine melanophloes - Hagenia abyssinica* community

This community was distributed at altitudes between 2753 and 2932 m.a.s.l. with mean altitude of 2847 m.a.s.l. This community is restricted to mountainous area locally known as '*bore*'. *Erica arborea*, *Osyris quadripartita*, *Myrsine melanophloes* were dominant plant species in this area (Figure 11). Arundinaria alpina is located in the wetter western side of the mountain. The diversity of this community is very low compared to the other four communities. Disturbance is relatively high in this community. Grazing, clearing the forest for agriculture and wood extraction is common in this area. People in this area are collecting Erica arborea for firewood, bamboo for house construction.

Figure 11. Partial view of area where species belongs to community 5 at the Afromontane forest of TBB exist (own photo)

Species in upper storey in this community include *Olea capensis* subsp. *macrocarpa* and *Juniperus procera*. Species in middle storey in this community include *Arundinaria alpina*, *Myrsine melanophloes*, *Hagenia abyssinica*, *Olinia rochetiana* and *Ilex mitis*. Species in lower storey include *Erica arborea* and *Maytenus addat*. Understory species in this community includes *Setaria megaphylla*, *Acanthus eminens*, *Acanthopale pubescens* and *Oplismenus hirtellus*.

Result from the cluster analysis shows that plants from the sample plots at the Afromontane forest of CCNP were grouped into three plant communities (Figure 12).

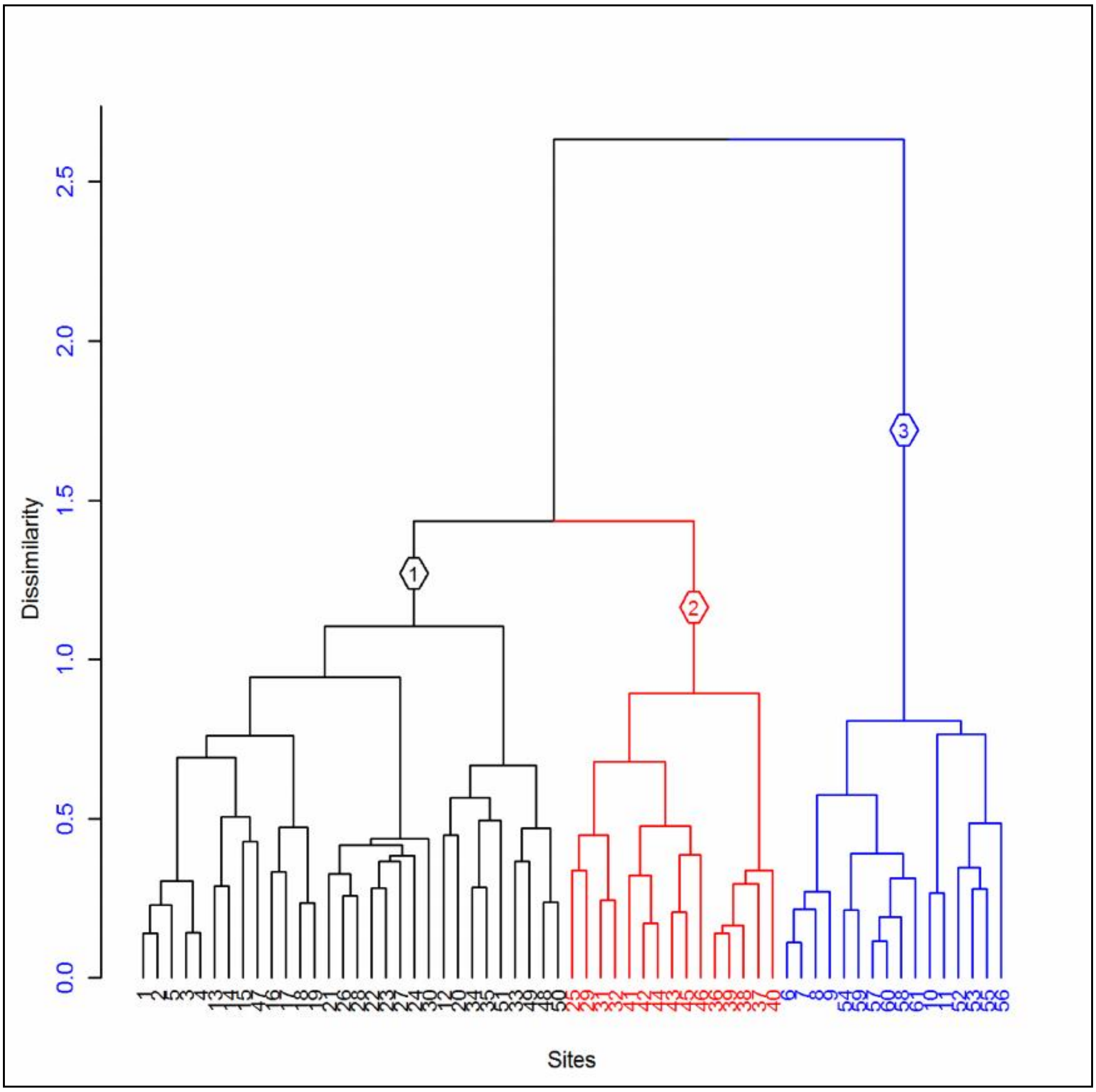

Figure 12. Dendrogram showing clusters of plots obtained from the Afromontane forest at CCNP

Cluster numbers in the dendrogram corresponds to the communities in the subsequent discussion. These clusters were designated as local plant communities and given names after two indicator species with higher species indicator value (Annex 5).

Community 1: ***Olea capensis subsp. macrocarpa - Macaranga capensis*** **community**

This community was distributed at altitudes between 1737 and 2339 m.a.s.l. with an average altitude of 2007 m.a.s.l. Species in upper storey in this community include *Syzygium guineense* subsp. *afromontanum*, *Prunus africana*, *Albizia gummifera* and *Olea capensis* subsp. *macrocarpa*. Species in the middle storey include *Lepidotrichilia volkensii*, *Ficus sur*, *Apodytes dimidiata*, *Macaranga capensis*, *Millettia ferruginea* subsp. *darassana*, *Polyscias fulva*, *Pouteria adolfi–friederici*, *Ilex mitis*, *Croton macrostachyus*, *Dombeya torrida*, *Vepris dainellii*, *Schefflera abyssinica* and *Allophylus abyssinicus*. Species in lower storey include *Psychotria orophila*, *Chionanthus mildbraedii*, *Oxyanthus speciosus*, *Dracaena afromontana*, *Maytenus gracilipes* subsp. *arguta*, *Pittosporum viridiflorum*, *Rytigynia neglecta* and *Galiniera saxifraga*. Understory species in this community includes *Desmodium repandum*, *Oplismenus hirtellus* and *Piper capense*.

Community 2. ***Cyathea manniana - Lepidotrichilia volkensii*** **community**

This community was distributed at altitudes between 1682 and 2173 m.a.s.l. with an average altitude of 1950 m.a.s.l. This community was formed along valleys in more wetter areas. It was dominated by *Cyathea maniana*, a tree fern (Figure 13).

Figure 13. Partial view of *Cyathea maniana* dominated area at the Afromontane forest of CCNP (own photo)

Species in upper storey in this community include *Syzygium guineense* subsp. *afromontanum* and *Prunus africana*. Species in middle storey in this community include *Dracaena afromontana*, *Lepidotrichilia volkensii*, *Ficus sur*, *Polyscias fulva, Schefflera abyssinica*, *Millettia ferruginea* subsp. *darassana*, *Croton macrostachyus*, *Celtis africana*, *Allophylus abyssinicus*, *Ilex mitis*, and *Vepris dainellii*. Species in lower storey include *Chionanthus mildbraedii*, *Oxyanthus speciosus*, *Cyathea manniana*, *Psychotria orophila*, *Galiniera saxifraga*, *Rytigynia neglecta*, *Pittosporum viridiflorum*, *Maytenus gracilipes* subsp. *arguta,* and *Canthium oligocarpum*. Understory species in this community includes *Piper capense* and *Oplismenus hirtellus*.

Community 3. *Coffea arabica - Nuxia congesta* community

This community was distributed at altitudes between 1614 and 1852 m.a.s.l. with an average altitude of 1702 m.a.s.l. This community is composed of plots dominated by wild *Coffea arabica* and *Nuxia congesta* and *Agarista salicifolia*. The latter two species were highly dominant in relatively open area of the Afromontane forest at the park . Species in upper storey in this community include *Syzygium guineense* subsp. *afromontanum* and *Ilex mitis*. Species in middle storey in this community include *Agarista salicifolia*, *Croton macrostachyus*, *Nuxia congesta*, *Schefflera volkensii*, *Millettia ferruginea* subsp. *darassana*, *Apodytes dimidiata*, *Allophylus abyssinicus*, *Ficus sur*, *Celtis africana*, *Macaranga capensis* and *Schefflera abyssinica*. Species in lower storey include *Oxyanthus speciosus*, *Chionanthus mildbraedii*, *Coffea arabica*, *Dracaena afromontana*, *Psychotria orophila*, *Maytenus gracilipes* subsp. *arguta*, *Galiniera saxifrage*, *Maesa lanceolata*, *Rytigynia neglecta* and *Vepris dainellii*. Understory species in this community includes *Oplismenus hirtellus*, *Setaria megaphylla*, *Acanthopale pubescens,* and *Achyranthes aspera*.

4.2.1.2 Ordination

Ordination describes environmental variable that control distribution of species in the forest (Jongman *et al*., 1987). RDA was applied to determine environmental variables which are responsible for the distribution of plant species in the forest and Adonis permutation test to determine the statistical significance of the variables. RDA was plotted using cover abundance values of plant species and significant ($P \leq 0.05$) environmental variables (Figure 14 and 15). Direction of arrow shows the gradient of the environmental variable, and the length of the arrow shows its importance.

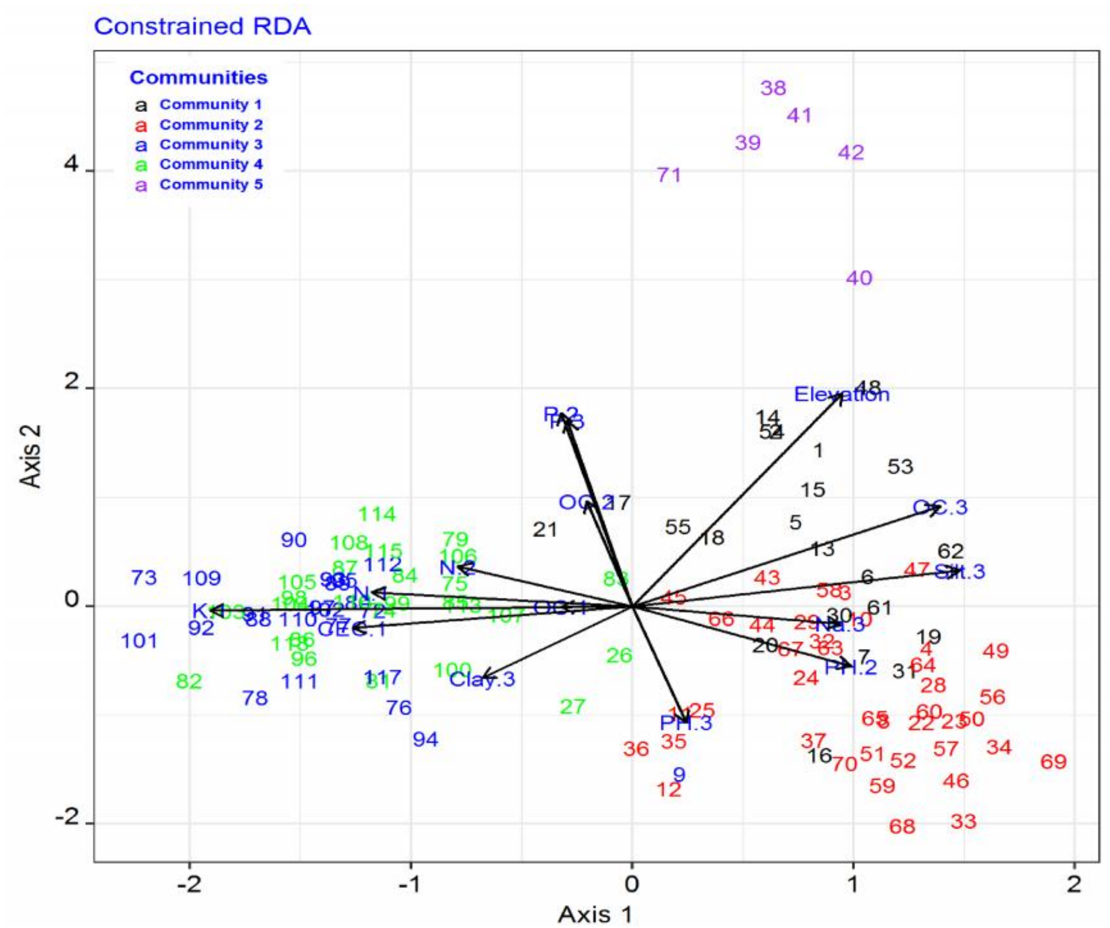

Figure 14. Constrained RDA for the plant communities at the Afromontane forest of TBB, showing the relationships of environmental variables correlated ($P \leq 0.05$) with sites *[numbers associated with environmental variables refer to the soil layer, where, 1 is for top layer which ranges from 0 – 10 cm, 2 is for middle layer which ranges from 10 – 20 cm and 3 is for lower layer which ranges from 20 – 50 cm]*

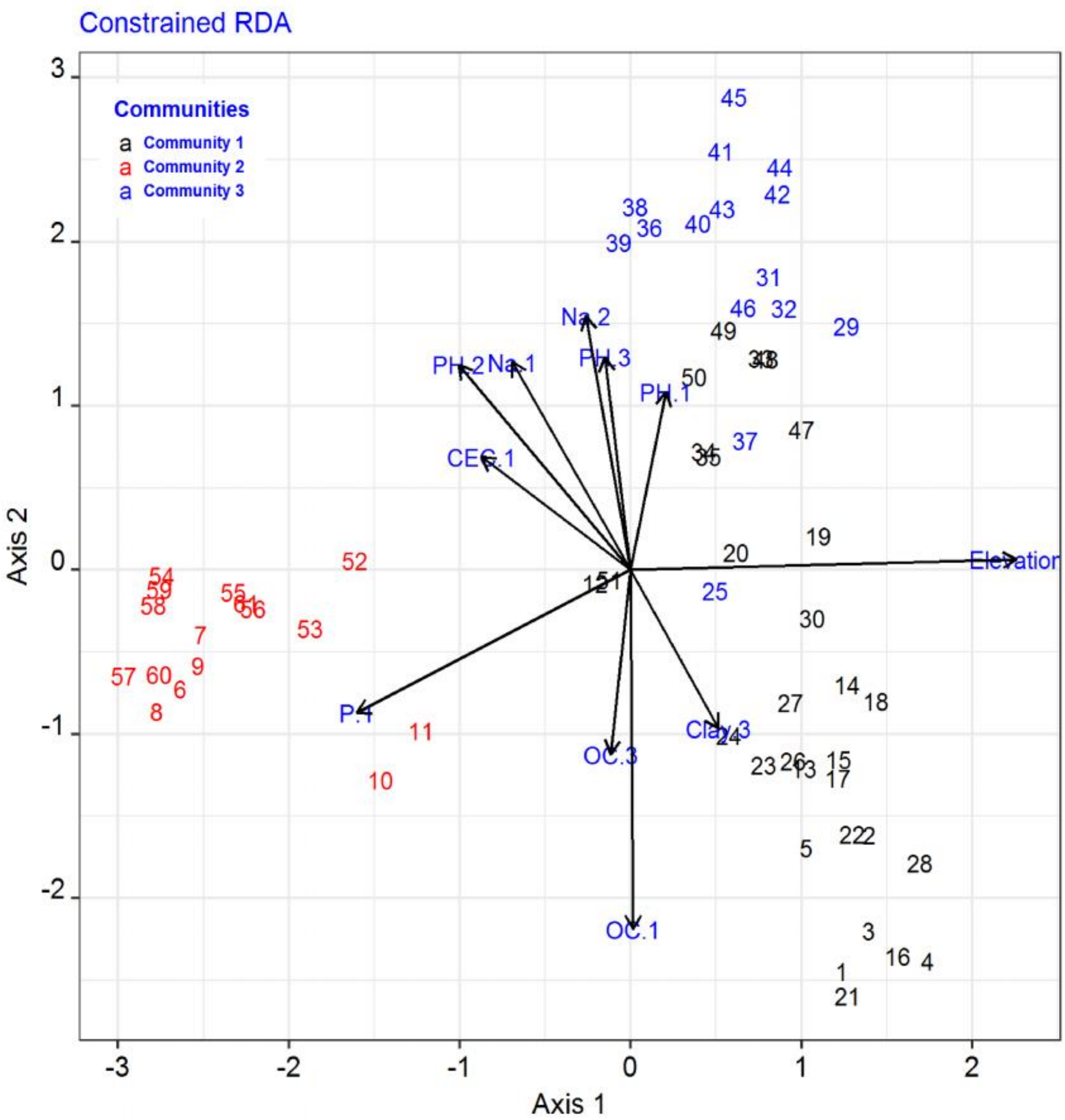

Figure 15. Constrained RDA for the plant communities at the Afromontane forest of CCNP showing the relationships of environmental variables correlated (P ≤ 0.05) with sites

According to the result obtained from RDA analysis variables that showed significance at p=0.05 at TBB are Elevation, P, OC, Silt, Na, pH, Clay, CEC, K, and N. Whereas variables that showed significance at p=0.05 at CCNP are P, CEC, pH, Na, Elevation, Clay, and OC. The significance of environmental variables at P=0.05 is given in Table 9 and Table 10 for TBB and CCNP respectively.

Table 9. Result of permutation test of environmental variables at TBB

Variable	Df	Sums of Sqs.	Mean Sqs.	F. Model	R2	Pr(>F)
PH.1	1	0.0668	0.06675	0.677	0.00416	0.8
PH.2	1	0.4245	0.4245	4.3053	0.02643	0.001 ***
PH.3	1	0.3882	0.38816	3.9367	0.02416	0.001 ***
OC.1	1	0.3278	0.32776	3.3241	0.0204	0.004 **
OC.2	1	0.2496	0.24961	2.5316	0.01554	0.006 **
OC.3	1	1.0173	1.01731	10.3176	0.06333	0.001 ***
N.1	1	0.4763	0.47628	4.8304	0.02965	0.001 ***
N.2	1	0.2368	0.23683	2.402	0.01474	0.009 **
N.3	1	0.0864	0.08639	0.8762	0.00538	0.562
P.1	1	0.1408	0.14078	1.4278	0.00876	0.111
P.2	1	0.6235	0.62352	6.3238	0.03882	0.001 ***
P.3	1	0.2022	0.20222	2.0509	0.01259	0.019 *
CEC.1	1	0.1877	0.18772	1.9039	0.01169	0.039 *
CEC.2	1	0.1675	0.16748	1.6986	0.01043	0.079 .
CEC.3	1	0.1285	0.12846	1.3029	0.008	0.196
Na.1	1	0.0891	0.08909	0.9036	0.00555	0.537
Na.2	1	0.0967	0.09674	0.9811	0.00602	0.444
Na.3	1	0.2771	0.27712	2.8105	0.01725	0.004 **
K.1	1	0.3687	0.36865	3.7389	0.02295	0.001 ***
K.2	1	0.1296	0.12963	1.3148	0.00807	0.224
K.3	1	0.0964	0.09635	0.9772	0.006	0.441
Clay.1	1	0.1678	0.16777	1.7015	0.01044	0.056 .
Clay.2	1	0.1098	0.1098	1.1136	0.00684	0.341
Clay.3	1	0.2243	0.22427	2.2745	0.01396	0.017 *
Sand.1	1	0.0955	0.09547	0.9683	0.00594	0.463
Sand.2	1	0.1599	0.15991	1.6219	0.00996	0.079 .
Sand.3	1	0.1444	0.14436	1.4641	0.00899	0.142
Silt.2	1	0.1082	0.10816	1.0969	0.00673	0.327
Silt.3	1	0.2461	0.24606	2.4956	0.01532	0.009 **
Elevation	1	0.3234	0.32343	3.2802	0.02013	0.001 ***
Slope	1	0.1329	0.13287	1.3476	0.00827	0.185
Aspect	1	0.1226	0.12264	1.2438	0.00763	0.253
Disturbance	1	0.1646	0.16463	1.6697	0.01025	0.052 .
Residuals	84	8.2824	0.0986		0.51561	
Total	117	16.0631			1	

Significance codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1

Table 10. Result of permutation test of environmental variables at CCNP

Variable	Df	Sums of Sqs.	Mean Sqs.	F. Model	R2	Pr(>F)
PH.1	1	0.1757	0.17572	2.2906	0.02457	0.047 *
PH.2	1	0.4033	0.40335	5.2579	0.05641	0.002 **
PH.3	1	0.2257	0.22568	2.9419	0.03156	0.017 *
OC.1	1	0.1826	0.18265	2.3809	0.02554	0.038 *
OC.2	1	0.0705	0.07048	0.9187	0.00986	0.435
OC.3	1	0.2854	0.2854	3.7203	0.03991	0.003 **
N.1	1	0.1157	0.11569	1.5081	0.01618	0.176
N.2	1	0.0838	0.08376	1.0918	0.01171	0.325
N.3	1	0.1042	0.10418	1.3581	0.01457	0.191
P.1	1	0.5355	0.53554	6.9812	0.0749	0.001 ***
P.2	1	0.0945	0.09446	1.2314	0.01321	0.232
P.3	1	0.1592	0.15921	2.0754	0.02227	0.061 .
CEC.1	1	0.2046	0.20457	2.6667	0.02861	0.018 *
CEC.2	1	0.0972	0.09717	1.2667	0.01359	0.226
CEC.3	1	0.1019	0.10187	1.3279	0.01425	0.215
Na.1	1	0.2409	0.24094	3.1408	0.0337	0.016 *
Na.2	1	0.1761	0.17612	2.2959	0.02463	0.043 *
Na.3	1	0.0945	0.09448	1.2316	0.01321	0.263
K.1	1	0.149	0.14895	1.9417	0.02083	0.068 .
K.2	1	0.1227	0.12273	1.5998	0.01716	0.136
K.3	1	0.1009	0.1009	1.3153	0.01411	0.202
Clay.1	1	0.0309	0.0309	0.4027	0.00432	0.921
Clay.2	1	0.1304	0.13039	1.6997	0.01823	0.109
Clay.3	1	0.1858	0.18585	2.4226	0.02599	0.040 *
Sand.1	1	0.0914	0.09138	1.1912	0.01278	0.238
Sand.2	1	0.1272	0.12716	1.6576	0.01778	0.127
Sand.3	1	0.0606	0.06065	0.7906	0.00848	0.575
Elevation	1	0.3046	0.30464	3.9712	0.0426	0.005 **
Slope	1	0.0303	0.03034	0.3955	0.00424	0.937
Aspect	1	0.1605	0.16049	2.0921	0.02244	0.055 .
Disturbance	1	0.0802	0.08023	1.0458	0.01122	0.366
Residuals	29	2.2247	0.07671		0.31112	
Total	60	7.1505			1	

Significance codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Importance of the constraining variables with their corresponding scores where axis one is the most important in explaining variation of patterns in species composition, and then variation explained by higher axes decreases successively (Kent and Cooker, 1992). Cumulative proportion of variance explained by the first six axes of the joint plot in the constraining biplot at TBB and CCNP were 66.9 % and 47.1 % respectively. From the cumulative proportion of variance explained by the first six axes, the proportion of variation explained by the first two axes at TBB and CCNP were 60.68 % and 66.94 % respectively. Constraining variables highly correlated with axis one contributed more eigenvalues indicating that more variation was explained by these constraining variables. The eigenvalue for axis one was the highest than the eigenvalues of the remaining five axes. The constraining variables of all the significant variables (p=0.05) are given in Table 11 and Table 12.

Table 11. Biplot scores for constraining variables at TBB

Variable	RDA1	RDA2	RDA3	RDA4	RDA5	RDA6
PH.2	0.399	-0.196	-0.056	-0.003	0.000	-0.126
PH.3	0.110	-0.417	-0.180	0.274	-0.053	0.188
OC.1	-0.133	0.001	-0.405	-0.196	0.198	-0.272
OC.2	-0.084	0.343	0.015	-0.112	0.049	0.344
OC.3	0.548	0.355	0.013	0.064	0.137	0.086
N.1	-0.469	0.019	-0.079	-0.078	-0.056	0.143
N.2	-0.315	0.095	-0.085	0.115	0.187	0.341
P.2	-0.142	0.659	-0.211	0.234	0.087	0.169
P.3	-0.134	0.635	-0.218	0.268	-0.030	0.281
CEC.1	-0.504	-0.112	0.033	-0.207	0.056	0.036
Na.3	0.385	-0.057	0.215	0.171	-0.216	0.203
K.1	-0.767	-0.039	0.187	0.070	-0.100	0.014
Clay.3	-0.259	-0.245	0.443	-0.326	-0.254	-0.035
Silt.3	0.586	0.134	-0.287	0.305	0.022	0.113
Elevation	0.364	0.739	0.058	-0.123	0.268	0.174
Eigenvalue	13.688	9.380	4.760	3.902	3.365	2.946
Proportion Explained	0.241	0.165	0.084	0.069	0.059	0.052
Cumulative Proportion	0.241	0.406	0.489	0.558	0.617	0.669

Table 12. Biplot scores for constraining variables at CCNP

Variable	RDA1	RDA2	RDA3	RDA4	RDA5	RDA6
PH.1	0.074	-0.362	-0.156	-0.021	0.130	-0.252
PH.2	-0.356	-0.393	-0.120	0.128	0.199	0.203
PH.3	-0.061	-0.449	-0.025	0.080	0.011	0.060
OC.1	0.014	0.724	0.098	-0.161	-0.296	-0.041
OC.3	-0.032	0.378	0.221	0.029	-0.013	0.120
P.1	-0.547	0.316	-0.047	-0.203	0.017	0.077
CEC.1	-0.295	-0.214	0.366	-0.147	0.383	-0.208
Na.1	-0.247	-0.433	-0.084	0.016	-0.036	0.015
Na.2	-0.098	-0.479	-0.524	0.280	0.210	0.160
Clay.3	0.180	0.321	0.055	-0.315	0.206	0.121
Elevation	0.763	-0.073	0.152	-0.136	-0.085	0.315
Eigenvalue	32.573	11.882	7.518	5.769	4.876	3.882
Proportion Explained	0.231	0.084	0.053	0.041	0.035	0.027
Cumulative Proportion	0.231	0.315	0.368	0.409	0.443	0.471

The constraining variable with the highest score associated to the first axes was potassium (0.767) and elevation (0.763) in TBB and CCNP respectively. Potassium and elevation were the most important variable in weighing axis one of the ordination at the respective forests. Similarly, elevation was the most important constraining variable in weighing axis two in TBB and Organic Carbon in CCNP with the biplot score of 0.739 0.724 respectively.

4.2.2 Diversity of Plant Communities

The Shannon–Wiener diversity indices of species for communities at the Afromontane forest of TBB (Table 13) showed that, community 4 had the highest diversity followed by communities 3, community 2 and community 1. Whereas, community 5 had the lowest diversity compared to other communities in this Afromontane forest. The species richness values among communities at the Afromontane forest of TBB were almost comparable except for community 5, which had the least evenness value.

Table 13. Species richness, evenness, and diversity of the five plant communities of the Afromontane forest of TBB

Communities	Richness (N)	Diversity (H’)	Evenness (E)
1	45	2.91	0.76
2	53	3.13	0.79
3	47	3.36	0.87
4	49	3.43	0.88
5	25	1.94	0.60

On the other hand, the Shannon–Wiener diversity indices of communities at the Afromontane forest of CCNP (Table 14) showed that, community 1 had the highest diversity followed by community 2. Whereas community 3 had, the least diversity compared to the other two communities in this forest. Similarly, the species richness values among communities at the Afromontane forest of CCNP were almost comparable.

Table 14. Species richness, evenness, and diversity in the three plant communities of the Afromontane forest of CCNP

Community	Richness (N)	Diversity (H’)	Evenness (E)
1	45	3.21	0.84
2	46	3.16	0.83
3	44	3.12	0.82

4.2.3 Plant Population Structure of the Afromontane forest of TBB and CCNP

Diameter and Height Class Distributions

The highest DBH recorded at the Afromontane forest of TBB was 239 cm for *Schefflera abyssinica* followed by 191 cm and 182 cm for *Prunus africana* and

Juniperus procera respectively. Regarding the height measurement, the highest height of a tree was recorded for *Olea capensis* subsp. *macrocarpa* (40 m) followed by *Pouteria adolfi–friederici* (30 m) and *Albizia gummifera* (28 m).

In the patterns of distribution of individuals to DBH classes at the Afromontane forests of TBB, the density of individuals of woody species gradually decreased from DBH-class 1 to DBH-class 10 and increased at DBH-class 11. The height-class distribution of this forest showed similar pattern with DBH-classes distribution with slight increment at height-class 8. Both the DBH-class (Figure 16) and Height-class (Figure 17) distributions of the forest showed an inverted J – shape pattern indicating that the forest has a healthy growth pattern. Densities of each woody species to their DBH- and Height-classes are presented in Annex 6 and Annex 7 respectively.

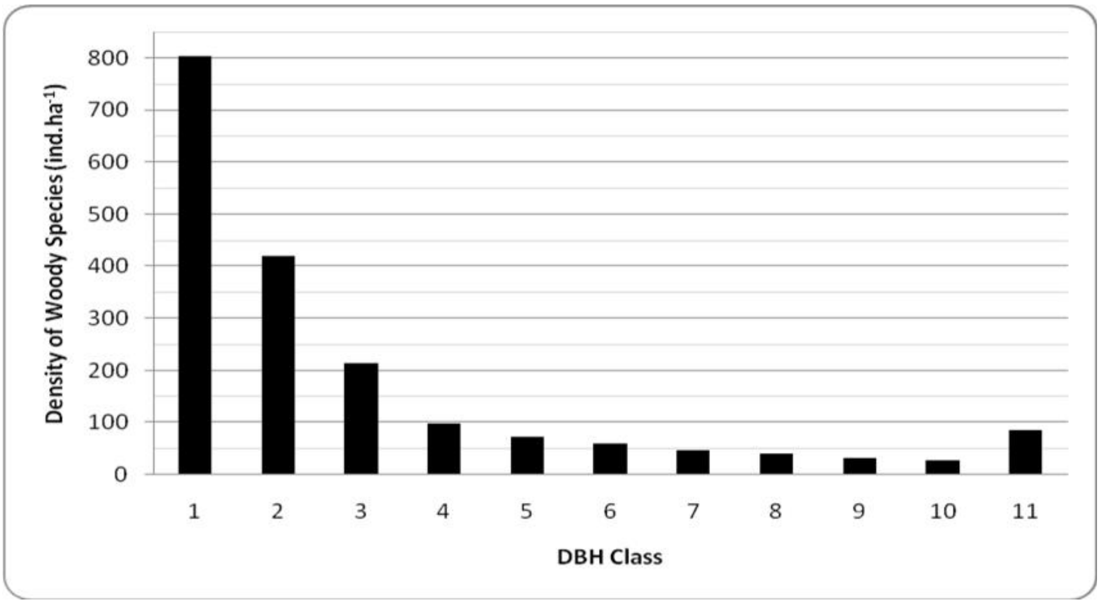

Figure 16. Distribution of individuals of woody species across DBH Class at the Afromontane forest of TBB. (DBH-class 1 = 2.5 cm – 6 cm, 2 = 6 cm – 10 cm, 3 = 10 cm – 15 cm, 4 = 15 cm – 20 cm, 5 = 20 cm – 25 cm, 6 = 25 cm – 30 cm, 7 = 30 cm – 35 cm, 8 = 35 cm – 40 cm, 9 = 40 cm – 45 cm, 10 = 45 cm – 50 cm and 11 = > 50 cm).

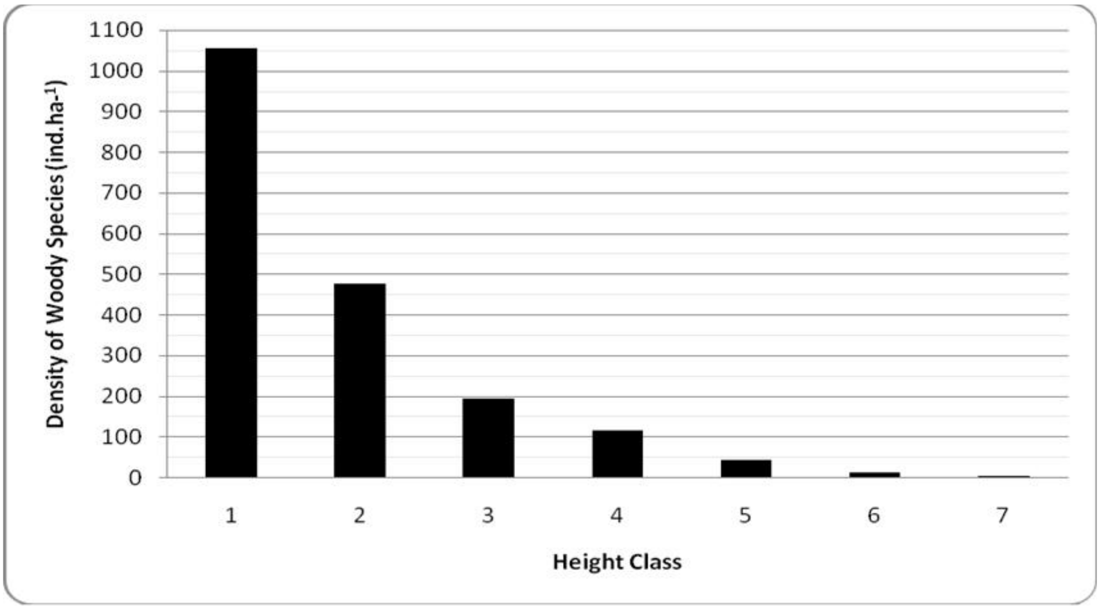

Figure 17. Distribution of individuals of woody species across Height Class at the Afromontane forest of TBB (height-class 1 = 2 m – 5 m, 2 = 5 m – 8 m, 3 = 8 m – 11 m, 4 = 11 m – 14 m, 5 = 14 m – 17 m, 6 = 17 m – 20 m, 7 = > 20 m).

On the other hand, the highest DBH recorded in CCNP was for *Albizia gummifera, which was* 223 cm, followed by *Olea capensis* subsp. *macrocarpa* (105 cm) and *Pouteria adolfi-friederici* (74 cm). Regarding height measurement, the highest height was recorded for *Albizia gummifera* (35 m) followed by *Apodytes dimidiata* (28 m) and *Ilex mitis* (20 m). Both the DBH-class (Figure 18) and Height-class (Figure 19) distributions of the Afromontane forest of CCNP showed an inverted J – shape pattern with the density of varies at each DBH- and Height- classes.

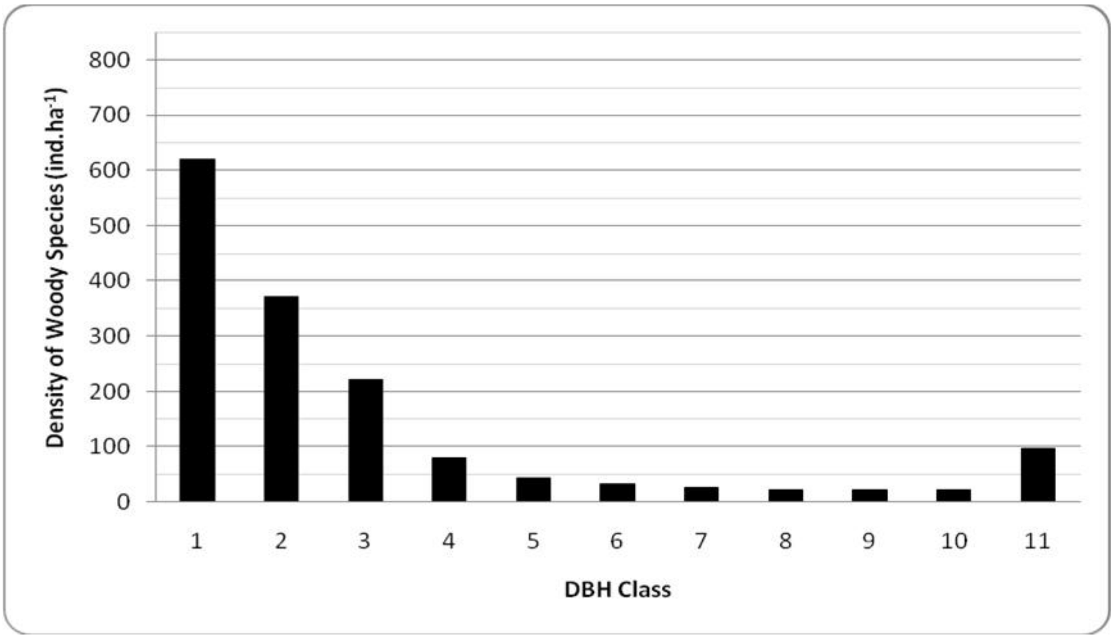

Figure 18. Distribution of individuals of woody species across DBH Class at the Afromontane forest of CCNP

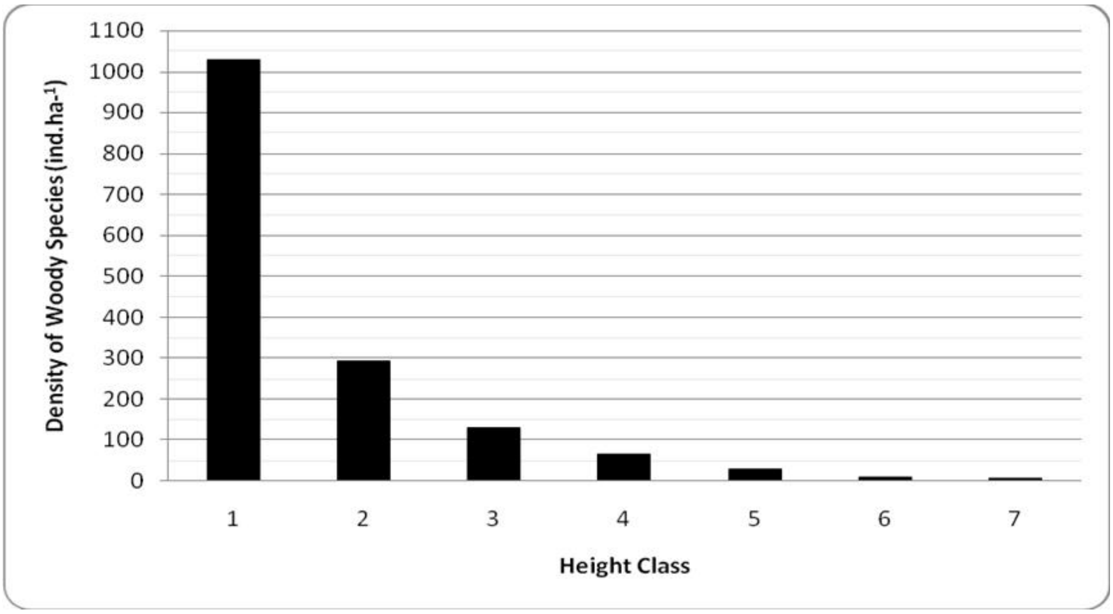

Figure 19. Distribution of individuals of woody species across Height Class at the Afromontane forest of CCNP

The density of individuals of woody species along DBH class gradually decreased from DBH-class 1 to DBH-class 10 and gradually increased at DBH-class 11 showing an inverted J– shape type. Similarly the pattern in height-class distribution was an inverted

J– shape with slight increment at height-class 8. Densities of woody species with respect to DBH- and Height-classes of the Afromontane forest of CCNP are given in Annex 8 and Annex 9 respectively.

Patterns of Population Structure of the Afromontane forests of TBB and CCNP

The diameter and height-class distribution patterns show trends of population change and recruitment processes of plants in a forest (Larsen and Bliss, 1998). Three and four main patterns of population structures of woody plant species were obtained from diameter-class distribution at the Afromontane forest of TBB (Figure 20) and CCNP (Figure 21) respectively.

The first pattern of population structure of woody species at the Afromontane forest of TBB is represented by *Podocarpus falcatus*. It approaches an inverted J–shape pattern. In this distribution pattern, species density distribution was the highest in the lower diameter classes and showed gradual decrease towards the higher diameter classes with further increase at diameter-class 11. Species included in this group are *Ilex mitis, Psychotria orophila,* and *Pouteria adolfi–friedrici*. The second pattern is represented by *Olea capensis* subsp. *macrocarpa.* In this pattern, species density distribution was becoming increasing from diameter-class 1 to diameter-class 2 and then decreases with increasing diameter up to diameter-class 10. It showed further increase at diameter-class 11. *Ficus sur, Syzygium guineense,* and *Olinia rochetiana* are species with the same distribution pattern. The third pattern is an undulating pattern, in which species density distribution shows alternation of increase and decrease in consecutive diameter classes. This pattern is represented by *Macaranga capensis.*

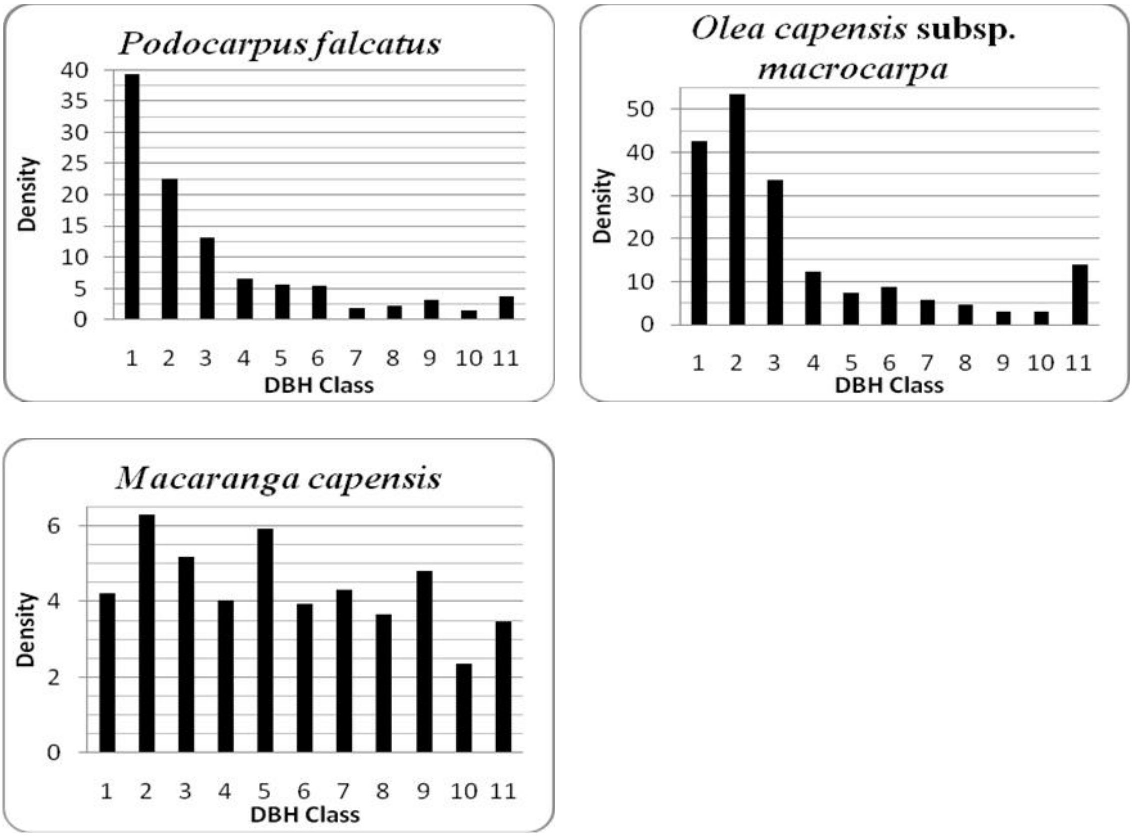

Figure 20. Structure of selected woody species with regard to DBH at the Afromontane forest of TBB

However, the first pattern of population structure of woody species at the Afromontane forest of TBB is represented by *Albizia gummifera*. It showed an inverted–J shaped pattern interrupted at diameter-class 4. In this pattern, density of woody species at DBH-class 4 showed remarkable decrease from its neighboring diameter classes. The second diameter-class distribution pattern is represented by *Agarista salicifolia*. It showed a bell–shaped pattern interrapted at diameter-class 4, 6 and 8. In these diameter classes density of woody species showed remarkable decrease from their neighboring diameter classes. The third diameter-class distribution pattern is represented by *Syzygium guineense*. In this pattern, species density distribution increased from diameter-class 1 to diameter-class 2 and then decreases with increasing diameter up to diameter-class 9. In addition, a further increase was observed at diameter-class 11. The forth diameter-class distribution pattern is represented by *Prunus africana*. It is U–shaped pattern having high density at diameter-class 1 and 11, with slight interruption in middle diameter-classes.

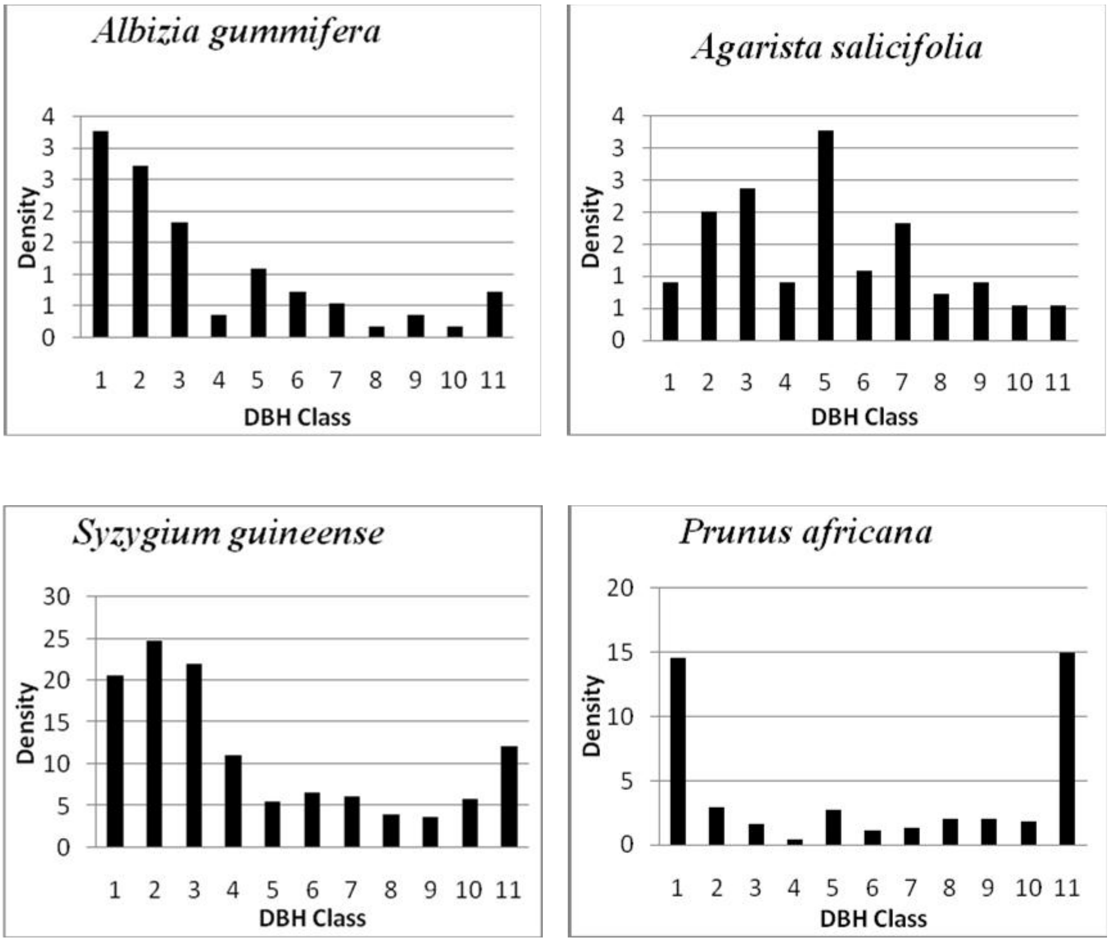

Figure 21. Structure of selected woody species with regard to DBH at the Afromontane forest of CCNP

On the other hand, the distribution of woody species at the Afromontane forest of TBB (Figure 22) and CCNP (Figure 23) showed two and four types of height-class distribution patterns respectively. The first pattern at the Afromontane forest of TBB, represented by *Syzygium guineense*, showed an inverted J–shape pattern. In this pattern, density of species at the first height-class was the highest and it decreases in the subsequent height-classes. *Chionanthus mildbraedii, Pouteria adolfi-friederici* and *Podocarpus falcatus* showed this pattern. The second pattern is represented by *Macaranga capensis*, where the species density distribution was becoming increasing from height-class 1 to height-class 2 and then decreases gradually in subsequent height-classes. *Ficus sur, Olea capensis* subsp. *macrocarpa* and *Macaranga capensis* are species showing this distribution pattern.

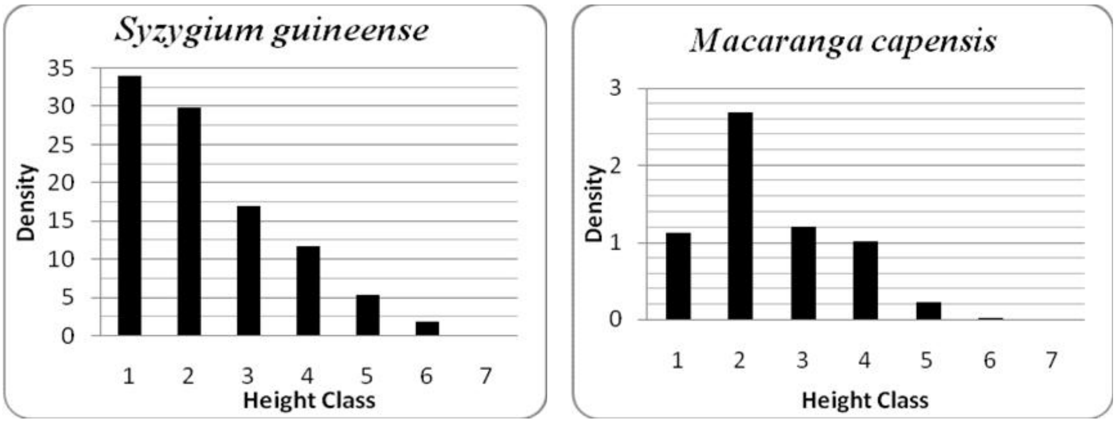

Figure 22. Structure of selected woody species with regard to Height at the Afromontane forest of TBB

Whereas the pattern at the Afromontane forest of CCNP, a bell–shaped pattern is represented by *Croton macrostachyus*. In this pattern, species density distribution showed increases from height-class 1 to height-class 3 and showed gradual decrease to height-class 5. The second height-class distribution pattern, an inverted–J pattern is represented by *Albizia gummifera*. In this pattern density of species was highest at the first height-class and decreasing in the subsequent height-classes. The third height-class distribution pattern, a zigzag height-class distribution pattern is represented by *Pouteria adolfi–friedricii*. In this pattern, density of species showed gradual decreases from height-class 1 to height-class 4. It then showed an increase in density in height-class 5 and showed gradual decrease afterwards. The forth height-class distribution pattern, an irregular height-class distribution pattern is represented by *Ilex mitis*. In this pattern, density of species showed an increase in density from height-class 1 to height-class 2. It then showed decrease in density at height-class 3 followed by slight increase at height-class 4. The density was then decreased at height-class 5 followed by slight decreases at consecutive height-classes.

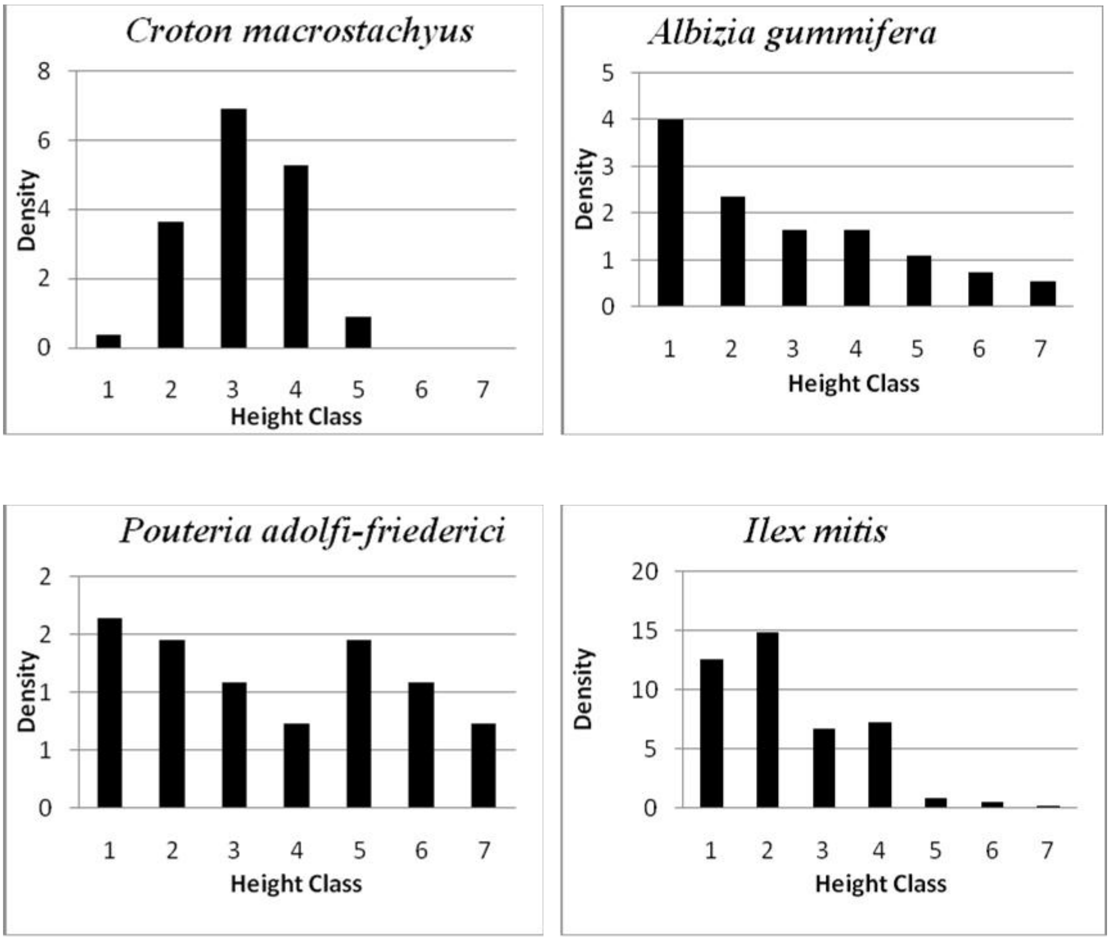

Figure 23. Structure of selected woody species with regard to Height at the Afromontane forest of CCNP

Density of Woody Species

Density of woody species at the Afromontane forest of TBB and CCNP were 1902 stems.ha^{-1} and 1562 stems.ha^{-1} respectively. The density of woody species at the Afromontane forest of TBB with DBH higher than 10 cm (a) and DBH higher than 20 cm (b) were 678 stems.ha^{-1} and 366 stems.ha^{-1} respectively with the ratio (a/b) of 1.9. Whereas the density of woody species at the Afromontane forest of CCNP with DBH higher than 10 cm (a) and DBH higher than 20 cm (b) were 570 stems.ha^{-1} and 269 stems.ha^{-1} respectively, and their ratio (a/b) is 2.1. Density, Basal area, Frequency, and IVI for woody species recorded at the Afromontane forest of TBB and CCNP are given in Annex 10 and 11 respectively.

Importance Value Index (IVI)

Ten most important woody species with IVI higher than 8 at the Afromontane forest of TBB is presented in Table 15.

Table 15. Importance Value Index of woody species with DBH ≥ 2.5 cm at TBB

No.	Plant Species	IVI	%
1	*Olea capensis* subsp. *macrocarpa*	28.63	9.54
2	*Syzygium guineense* subsp. *afromontanum*	28.43	9.48
3	*Pouteria adolfi–friederici*	16.54	5.51
4	*Podocarpus falcatus*	14.07	4.69
5	*Chionanthus mildbraedii*	13.81	4.60
6	*Olinia rochetiana*	11.16	3.72
7	*Macaranga capensis*	9.75	3.25
8	*Ficus sur*	9.39	3.13
9	*Psychotria orophila*	8.88	2.96
10	*Ilex mitis*	8.73	2.91
	Sum	**149.39**	**49.80**

Olea capensis subsp. *macrocarpa* had the highest IVI followed by *Syzygium guineense* subsp. *afromontanum*. Those ten species totally account for 49.80 % of the total IVI. Similarly, ten most important woody species of the Afromontane forest of CCNP with IVI higher than 10 was presented in Table 16. *Syzygium guineense* subsp. *afromontanum* had the highest IVI followed by *prunus africana* and *Oxyanthus speciosus*. Those ten species totally account for 49.2 % of the total IVI.

Table 16. Importance Value Index of woody species with DBH ≥ 2.5 cm at CCNP

No.	Plant Species	IVI	%
1	*Syzygium guineense* subsp. *afromontanum*	24.31	8.10
2	*Prunus africana*	15.84	5.28
3	*Oxyanthus speciosus*	15.05	5.02
4	*Chionanthus mildbraedii*	14.88	4.96
5	*Ilex mitis*	14.48	4.83
6	*Schefflera abyssinica*	14.31	4.77
7	*Dracaena afromontana*	14.18	4.73
8	*Ficus sur*	12.73	4.24
9	*Psychotria orophila*	11.09	3.70
10	*Pouteria adolfi–friederici*	10.74	3.58
	Sum	**147.61**	**49.20**

Basal area

Basal area of woody species at the Afromontane forests of TBB and CCNP are 72.98 m^2ha^{-1} and 73.81 m^2ha^{-1} respectively. From the total individuals of woody species obtained from the Afromontane forest of TBB, 4.46 % attained DBH greater than 50 cm. The higher DBH-class was occupied by 25 woody plant species, of which *Syzygium guineense* had the highest density (20.67 %) followed by *Olea capensis* subsp. *macrocarpa* (16.56 %) and *Pouteria adolfi–friedrici* (9.44 %). The remaining 22 woody plant species were accounting for 53.33 % of the total density at DBH-class 11. These species showed low recruitments and their contribution of total density was minimal.

On the other hand, only 6.22 % individuals of woody species attained DBH greater than 50 cm at the Afromontane forest of CCNP. The higher DBH-class was occupied by 20 woody plant species of which *Prunus africana* had the highest density (15.38 %)

followed by *Ilex mitis* (13.13 %), *Syzygium guineense* (12.57 %) and *Ficus sur* (11.26). The remaining 16 woody plant species together accounted for 47.65 % of the total density at DBH-class 11. The 16 woody plant species accounting for 47.65 % of the total density at DBH-class 11 had low recruitments and low contribution to the total density in the forest. Distribution of basal area across DBH-classes for TBB and CCNP are presented in Figure 24 and Figure 25 respectively.

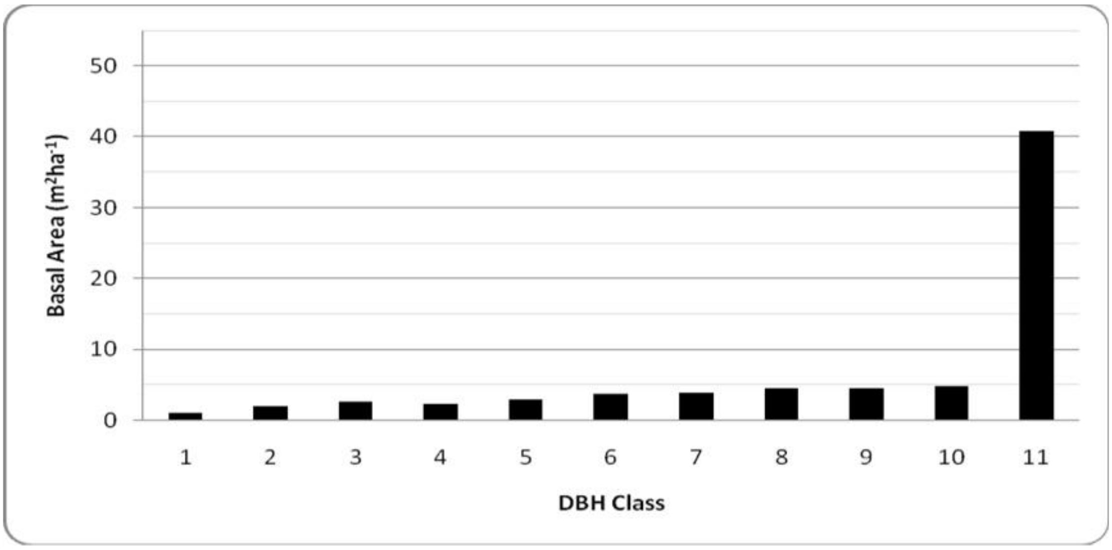

Figure 24. Distribution of Basal area across DBH classes at the Afromontane forest of TBB

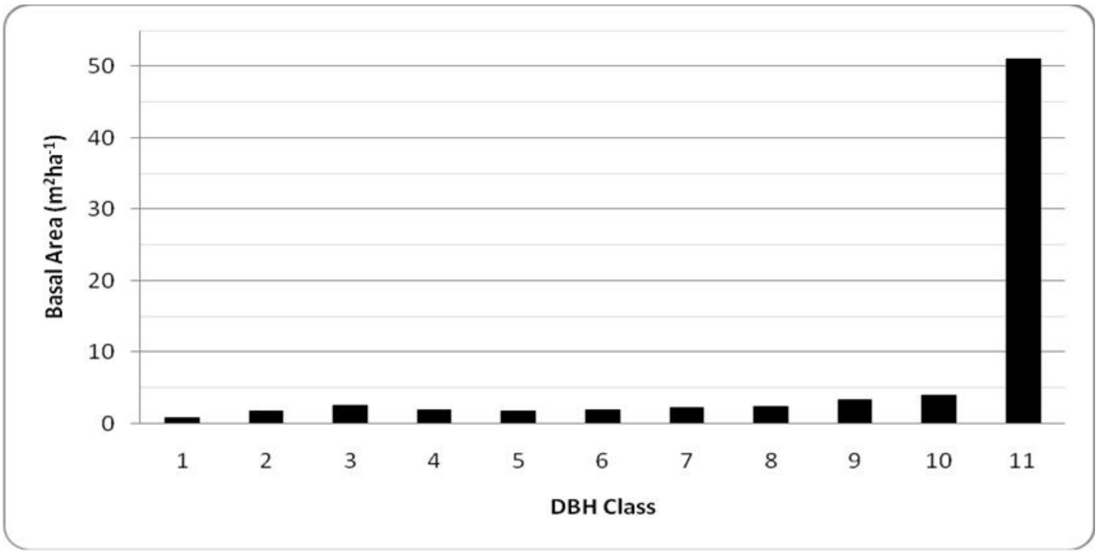

Figure 25. Distribution of Basal area across DBH classes at the Afromontane forest of CCNP

Vertical Structure of the Forest

Since the tallest tree at the Afromontane forest of TBB was *Olea capensis* subsp. *macrocarpa* (40 m), trees with height higher than 26.6 m were grouped into the upper storey, between 13.3 m and 26.6 m were grouped into middle storey and trees with height lower than 13.3 m were grouped into lower storey (Table 17). The three species occupying the upper storey at TBB were *Albizia gummifera* (7.69 %), *Olea capensis* subsp. *macrocarpa* (38.46 %), and *Pouteria adolfi–friederici* (53.85 %).

Table 17. Density, number of species, and ratios of individuals to species by storey at the Afromontane forest of TBB

Story	Density (Ind. ha^{-1})	%	No of species	%	Ratio of ind. ha^{-1} to species
Upper	1.22	0.06	3	4.00	0.41:1
Middle	94.73	4.98	25	33.33	3.79:1
Lower	1805.84	94.95	74	98.67	24.40:1

Whereas the tallest tree at the Afromontane forest of CCNP was *Albizia gummifera* (35 m). Trees with height higher than 23.3 m were grouped into upper storey, trees with height between 11.6 m and 23.3 m were grouped into middle storey and trees with height lower than 11.6 m were grouped into lower storey (Table 18). The highest density of stems was measured from the lower storey and the lowest density of stems was measured from the upper storey. Similarly, more species were found in the lower storey followed by the middle storey. The upper story had a least number of species when compared to the middle story and the lower storey. The two species occupying the upper storey at the Afromontane forest of CCNP were *Albizia gummifera* (97.30 %) and *Apodytes dimidiata* (2.70 %).

Table 18. Density, number of species, and ratios of individuals to species by storey at the Afromontane forest of CCNP

Story	Density (Ind. ha^{-1})	%	No of species	%	Ratio of ind. ha^{-1} to species
Upper	6.73	0.43	2	7.41	3.37:1
Middle	105.84	6.78	7	25.93	15.12:1
Lower	1449.36	92.79	27	100	53.68:1

4.2.5 Regeneration Status of Montane Forests at TBB and CCNP

54 and 58 species were recorded at the Afromontane forest of TBB as seedlings and saplings respectively with their corresponding density of 735.3 stems.ha^{-1} and 1558.4 stems.ha^{-1}. On the other hand, 41 species were recorded at the Afromontane forest of CCNP as both seedlings and saplings with seedlings and saplings density of 1005.3 stems.ha^{-1} and 755.7 stems.ha^{-1} respectively. A complete record of seedlings and saplings recorded at the Afromontane forests of TBB and CCNP are presented in Annex 12 and Annex 13.

4.3 Land use/Land cover Change

Landsat satellite images of the year 1984, 2000, and 2015 were used for the applications of image processing and classification at both TBB and CCNP. Four major LU/LC types were identified in TBB. These are (i) Forest, (ii) Woodland, (iii) Shrub/Bushland, and (iv) Agriculture and settlement (Figure 26).

The LU/LC classification of the year 1984 at TBB indicates that the greatest share of the total LU/LC area was from forest, which covered an area of 26384.40 ha (65.10 %). The land covered by Shrub/Bushland and Woodland were 6470.19 ha (15.97 %) and 5300.01 ha (13.08 %) respectively. Whereas, land covered by Agriculture and settlement was 2373.48 ha (5.86 %).

For the LU/LC of the year 2000 at TBB, the highest share of the total LU/LC area was from Forest, which was 29461.14 ha (72.69 %) followed by Agriculture and settlement which covered 4228.02 ha (10.43 %). Land covered by Woodland and Shrub/Bushland were 3703.50 ha (9.14 %) and 3135.42 ha (7.74 %) respectively.

Result from the LU/LC classification at TBB for the year 2015 shows that the greatest portion of the total LU/LC area was covered by Forest, an area of 21070.44 ha (51.99 %) followed by Agriculture and settlement which was 8623.62 ha (21.28 %). LU/LC area for Shrub/Bushland and Woodland were 7950.06 ha (19.62 %) and 2883.96 ha (7.12 %) respectively.

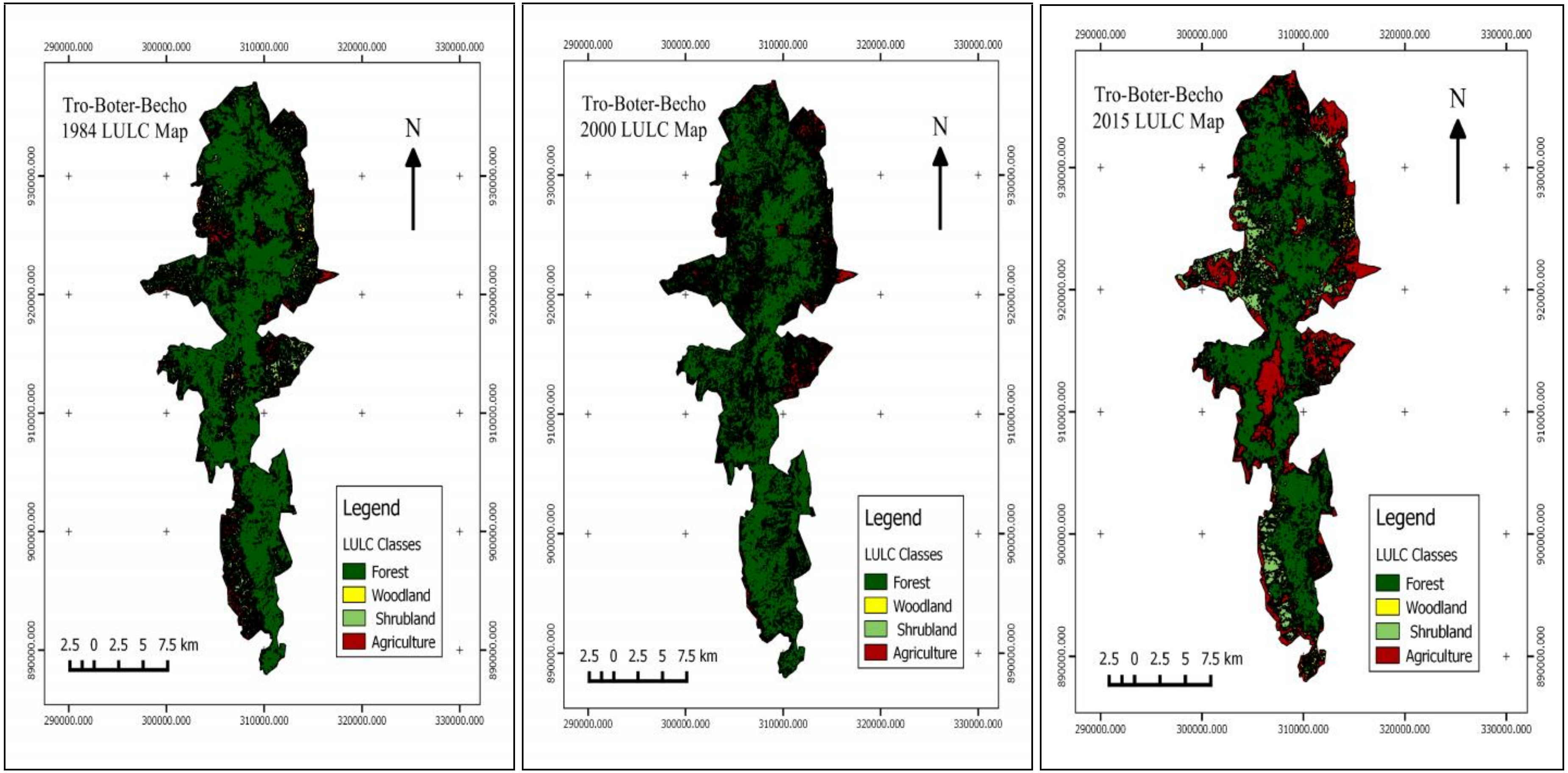

Figure 26. LU/LC map of TBB for the year 1984, 2000, and 2015

Regarding CCNP, five major LU/LC types were identified. These are: (i) Forest, (ii) Woodland, (iii) Grassland, (iv) Agriculture and Settlement, and (v) Water body (Figure 27).

LU/LC classification from the year 1984 indicates that the greatest portion of the total LU/LC area was from Woodland, which covered an area of 46912.00 ha (38.61 %). Grassland and Forest covered an area of 37688.22 ha (31.02 %) and 36114.56 ha (29.72 %) respectively, whereas land covered by Agriculture and Settlement was 335.01 ha (0.28 %) and land covered by Water body was 457.32 ha (0.38 %).

Unlike the LU/LC of the year 1984 at CCNP, the LU/LC classification at CCNP for the year 2000 showed that the greatest share of the total LU/LC area was from Grassland, which covered an area of 45814.43 ha (37.71 %) followed by Woodland, covering an area of 39012.11 ha (32.11 %). The Forest cover of the area was 35412.68 ha (29.14 %) and that of Agriculture and Settlement was 809.18 ha (0.67 %) of the total area. Whereas land covered by Water body was 458.80 ha (0.38 %).

Similarly, results from the LU/LC classification of the year 2015 shows that the greatest share of the total LU/LC area was from Grassland, which covered an area of 53896.93 ha (44.36%) followed by Forest, covering an area 34038.23 ha (28.01 %) of the total land of the study area. Woodland covered an area of 25302.75 ha (20.82 %). Agriculture and Settlement covered an area of 7809.14 ha (6.43 %). Whereas, land covered by Water body was 460.15 ha (0.38 %).

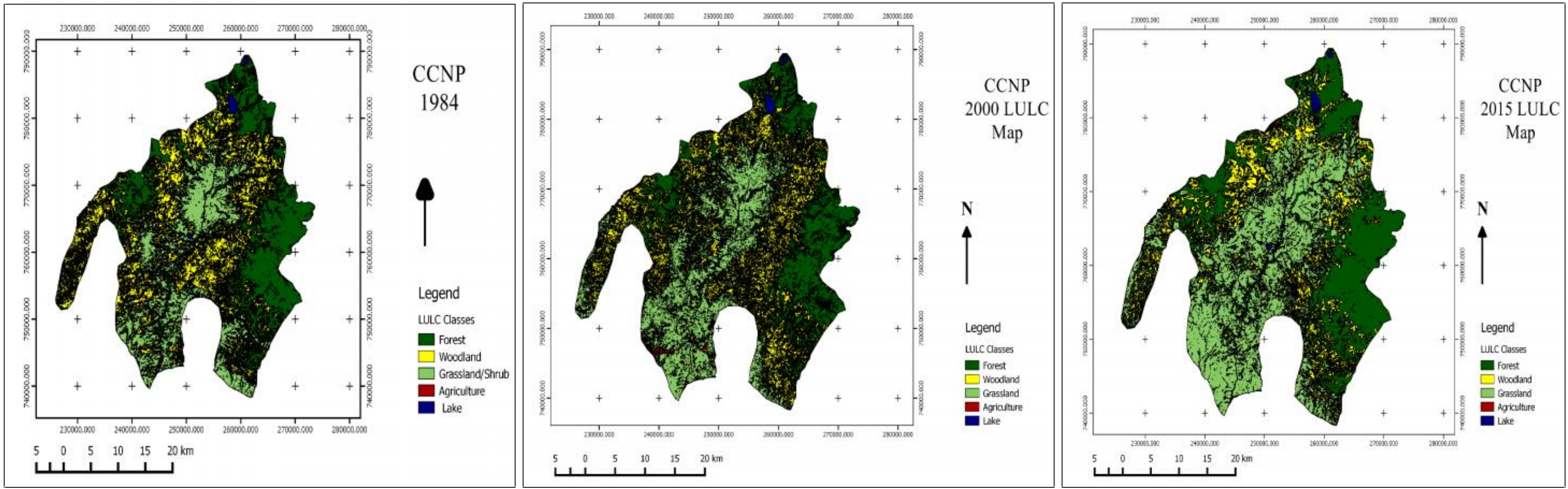

Figure 27. LU/LC map of CCNP for the year 1984, 2000, and 2015

Classification Accuracy

Classification accuracy assessment results for the 2015 classified images of TBB and CCNP are given in Table 19 and Table 20 respectively. The matrices indicate the nature of the classification error made during the assignment of LU/LC classes. The accuracy assessment was done based on pixel–by–pixel comparison and the data/number presented in the matrices is a pixel count assigned to the corresponding LU/LC class. Hence, the overall accuracy of the LU/LC classification at TBB was 96.09 % while the kappa coefficient of the classification was 0.90. Whereas the overall accuracy of the LU/LC classification at CCNP was 90.66 % while the kappa coefficient of the classification was 0.92.

Table 19. Classification accuracy for 2015 classified images of TBB.

LU/LC Class	Fr	Wd	Sh/Bu	Ag & Se	Class Total
Fr	**4014**	2	4	0	4020
Wd	8	**157**	11	0	176
Sh/Bu	147	36	**922**	1	1106
Ag & Se	0	0	3	**116**	119
Class Total	4169	195	940	117	5421

Fr= Forest, Wd= Woodland, Sh/Bu= Shrub/Bushland, Ag & Se= Agriculture & Settlement

Table 20. Classification accuracy for 2015 classified images of CCNP

Class	Fr	Wd	Gr	Ag & Se	Wa	Class Total
Fr	**15505**	10	228	0	0	15743
Wd	40	**875**	562	8	0	1485
Gr	2	2	**28889**	1	0	28894
Ag & Se	3	62	161	**30**	0	256
Wa	0	0	34	0	**90**	124
Class Total	15550	949	29874	39	90	46502

Fr= Forest, Wd= Woodland, Gr= Grassland, Ag & Se= Agriculture & Settlement, Wa= Water body

4.4 Change Detection of LU/LC

The change detection given in Table 21, Table 22, and Table 23 show area of both unchanged and changed LU/LC types in TBB from the year 1984 to 2000, 2000 to 2015, and 1984 to 2015 respectively.

Table 21. LU/LC change at TBB from the year 1984 to 2000

LULC Class		2000									
		Area									
		Fr		Wd		Sh/Bu		Ag & Se		**Class Total**	
		ha	%	ha	%	ha	%	ha	%	ha	%
1984	Fr	**23456.16**	88.90	1310.76	4.97	1182.51	4.48	434.97	1.65	26384.4	65.10
	Wd	2847.78	53.73	**1227.69**	23.16	607.77	11.47	616.77	11.64	5300.01	13.08
	Sh/Bu	2381.31	36.80	964.71	14.91	**1043.19**	16.12	2080.98	32.16	6470.19	15.96
	Ag & Se	775.89	32.69	200.34	8.44	301.95	12.72	**1095.3**	46.15	2373.48	5.86
	Class Total	29461.14	72.69	3703.5	9.14	3135.42	7.74	4228.02	10.43	**40528.1**	100.00
Class change		6004.98	20.38	2475.81	66.85	2092.23	66.73	3132.72	74.09	0.00	0.00
Image difference		3076.74		-1596.51		-3334.77		1854.54			

Fr= Forest, Wd= Woodland, Sh/Bu= Shrub/Bushland, Ag & Se= Agriculture & Settlement

Table 22. LU/LC change at TBB from the year 2000 to 2015

LULC Class		2015 Area Fr ha	Fr %	Wd ha	Wd %	Sh/Bu ha	Sh/Bu %	Ag & Se ha	Ag & Se %	**Class Total** ha	**Class Total** %
2000	Fr	**19142.64**	64.98	2340.36	7.94	5303.25	18.00	2674.89	9.08	29461.1	72.69
	Wd	818.46	22.10	**328.5**	8.87	1195.2	32.27	1361.34	36.76	3703.5	9.14
	Sh/Bu	875.43	27.92	142.47	4.54	**728.1**	23.22	1389.42	44.31	3135.42	7.74
	Ag & Se	233.91	5.53	72.63	1.72	723.51	17.11	**3197.97**	75.64	4228.02	10.43
	Class Total	21070.44	51.99	2883.96	7.12	7950.06	19.62	8623.62	21.28	**40528.1**	100.00
Class change		1927.8	9.15	2555.46	88.61	7221.96	90.84	5425.65	62.92	0.00	0.00
Image change		-8390.7		-819.54		4814.64		4395.6			

Fr= Forest, Wd= Woodland, Sh/Bu= Shrub/Bushland, Ag & Se= Agriculture & Settlement

Table 23. LULC change at TBB from the year 1984 to 2015

LULC Class		**2015**									
		Area									
		Fr		Wd		Sh/Bu		Ag & Se		**Class Total**	
		ha	%	ha	%	ha	%	ha	%	ha	%
1984	Fr	**19108.6**	72.42	1913.58	7.25	3658.68	13.87	1703.52	6.46	26384.4	65.10
	Wd	1126.89	21.26	**530.28**	10.01	1727.91	32.60	1914.93	36.13	5300.01	13.08
	Sh/Bu	651.33	10.07	371.25	5.74	**1895.49**	29.30	3552.12	54.90	6470.19	15.96
	Ag & Se	183.6	7.74	68.85	2.90	667.98	28.14	**1453.05**	61.22	2373.48	5.86
	Class Total	21070.4	51.99	2883.96	7.12	7950.06	19.62	8623.62	21.28	**40528.1**	100.00
Class change		1961.8	9.31	2353.68	81.61	6054.57	76.16	7170.57	83.15	0.00	0.00
Image difference		-5314		-2416.05		1479.87		6250.14			

Fr= Forest, Wd= Woodland, Sh/Bu= Shrub/Bushland, Ag & Se= Agriculture & Settlement

Area of changed and unchanged LU/LC types in CCNP from the year 1984 to 2000, 2000 to 2015, and 1984 to 2015 are given in Table 24, Table 25, and Table 26 respectively.

Table 24. LULC change at CCNP from the year 1984 to 2000

LULC Class		2000											
		Area											
		Fr		Wd		Gr		Ag & Se		Wa		**Class Total**	
		Ha	%	Ha	%	ha	%	ha	%	ha	%	ha	%
1984	Fr	**35285.94**	97.71	510	1.41	127.02	0.35	191.69	0.53	0	0.00	36,114.65	29.72
	Wd	65.48	0.14	**38405.21**	81.87	8129.3	17.33	312.01	0.67	0	0.00	46,912.00	38.61
	Gr	50.26	0.13	95.9	0.25	**37538.48**	99.60	3.1	0.01	1.48	0.00	37,689.22	31.02
	Ag & Se	11	3.28	2	0.60	19.63	5.86	**302.38**	90.26	0	0.00	335.01	0.28
	Wa	0	0.00	0	0.00	0	0.00	0	0.00	**457.32**	100.00	457.32	0.38
	Class Total	35,412.68	29.14	39,013.11	32.11	45,814.43	37.70	809.18	0.67	458.80	0.38	**121,508.20**	100.00
Class change		126.74	0.36	607.90	1.56	8,275.95	18.06	506.80	62.63	1.48	0.32	0.00	0.00
Image change		-701.97		-7,898.89		8,125.21		474.17		1.48			

Fr= Forest, Wd= Woodland, Gr= Grassland, Ag & Se= Agriculture & Settlement, Wa= Water body

Table 25. LULC change at CCNP from the year 2000 to 2015

LULC Class		**2015**											
		Area											
		Fr		Wd		Gr		Ag & Se		Wa		**Class Total**	
		Ha	%	Ha	%	ha	%	ha	%	ha	%	ha	%
2000	Fr	**34013.76**	96.05	115.48	0.33	180	0.51	1103.44	3.12	0	0.00	35,412.68	29.14
	Wd	16.03	0.04	**25175.17**	64.53	7949.89	20.38	5871.02	15.05	0	0.00	39,012.11	32.11
	Gr	5.24	0.01	10.56	0.02	**45760.12**	99.88	37.07	0.08	1.35	0.00	45,814.43	37.71
	Ag & Se	3.2	0.40	1.45	0.18	6.92	0.86	**797.61**	98.57	0	0.00	809.18	0.67
	Wa	0	0.00	0	0.00	0	0.00	0	0.00	**458.8**	100.00	458.8	0.38
	Class Total	34,038.23	28.01	25,302.66	20.82	53,896.93	44.36	7,809.14	6.43	460.15	0.38	**121,507.20**	100.00
Class change		24.47	0.07	127.49	0.50	8,136.81	15.10	7,011.53	89.79	1.35	0.29	0.00	0.00
Image change		-1,374.45		-13,709.45		8,082.50		6,999.96		1.35			

Fr= Forest, Wd= Woodland, Gr= Grassland, Ag & Se= Agriculture & Settlement, Wa= Water body

Table 26. LULC change at CCNP from the year 1984 to 2015

LULC Class		2015 Area: Fr		Wd		Gr		Ag & Se		Wa		**Class Total**	
		Ha	%	Ha	%	ha	%	ha	%	ha	%	ha	%
1984	Fr	**34005.23**	94.16	203.70	0.56	111.81	0.31	1793.91	4.97	0.00	0.00	36114.65	29.72
	Wd	20.43	0.04	**25092.75**	53.49	16127.80	34.38	5671.02	12.09	0.00	0.00	46912.00	38.61
	Gr	7.35	0.02	4.20	0.01	**37645.62**	99.89	28.22	0.07	2.83	0.01	37688.22	31.02
	Ag, & Se	5.22	1.56	2.10	0.63	11.70	3.49	**315.99**	94.32	0.00	0.00	335.01	0.28
	Wa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**457.32**	100.00	457.32	0.38
	Class Total	34038.23	28.01	25302.75	20.82	53896.93	44.36	7809.14	6.43	460.15	0.38	**121507.20**	100.00
Class change		33.00	0.10	210.00	0.83	16,251.31	30.15	7,493.15	95.95	2.83	0.62	0.00	0.00
Image change		-2,076.42		-21,609.25		16,208.71		7,474.13		2.83			

Fr= Forest, Wd= Woodland, Gr= Grassland, Ag & Se= Agriculture & Settlement, Wa= Water body

4.5 Rate of LC/LC Changes

There were variations among the rate of changes in the LU/LC types at TBB and CCNP in various periods under study. In the entire study period (from year 1984 to 2015), Forest cover was changed from 26384.40 ha to 21070.44 ha at a rate of 171.42 ha per year. Woodland cover was also changed from 5300.01 ha to 2883.96 ha at a rate of 77.94 ha per year. However, Shrub/Bushland cover was changed from 6470.19 ha to 7950.06 ha at a rate of 47.74 ha per year. Agriculture and Settlement were changed from 2373.48 ha to 8623.62 ha at a rate of 201.62 ha per year. The rate of change of LU/LC types at TBB is given in Figure 28.

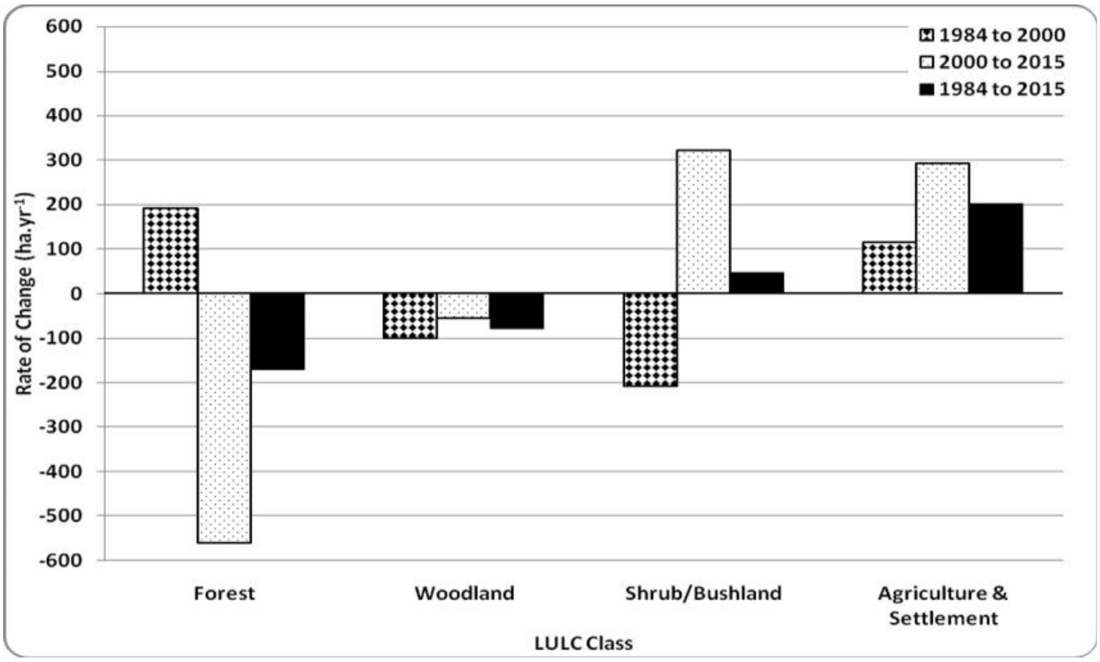

Figure 28. Annual Rate of Land Use/Land Cover change in TBB from 1984 to 2000, from 2000 to 2015, and from 1984 to 2015

In CCNP, Forest cover was changed from 36114.65 ha to 34038.23 ha from year 1984 to 2015, at a rate of -66.98 ha per year. Woodland cover was changed from 46912.00 ha to 253.2.75 ha at a rate of -697.07 ha per year. Grassland cover was changed from 37688.22 ha to 45814.43 ha at a rate of 522.86 ha per year. Agriculture Settlement were changed increased from 335.01 ha to 7809.14 ha at a rate of 241.10 ha per year. Change in the water body was also detected from 457.32 ha in 1984 to 460.15 ha in 2015 at a rate of 0.09 ha per year. The rate of change of LU/LC types at CCNP is given in Figure 29.

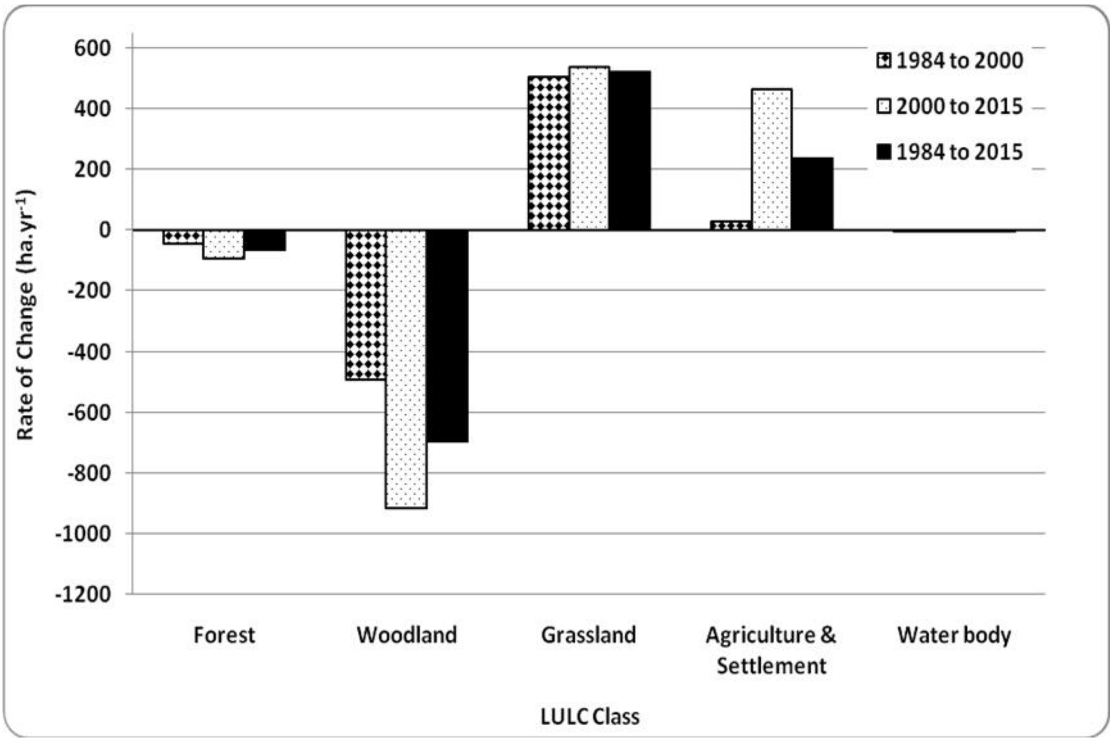

Figure 29. Annual Rate of Land Use/Land Cover change in CCNP from 1984 to 2000, from 2000 to 2015, and from 1984 to 2015

4.6 Summary of Results of Key Informant Interviews and Focus Group Discussions

Among the main economic activities in TBB and CCNP, Agriculture was the first followed by petty trade and employment (permanent employment in OFWE and contract as daily laborer). In addition, some people living around the park hunt small wild animals for food. It was reported that human population of local community around forest in both study areas were increasing from time to time. As a result the demand for agriculture and land for house construction is increasing. This demand was usually fulfilled through conversion of forested areas. Most households living in the study area own land used for agriculture and house construction. Only few households in TBB, who own land were planted woodlots in their plots. None of the households living inside or around CCNP were planted trees for their consumption. They simply collect from the forest inside or around the park.

People living adjacent to the forest uses the forest as source of firewood, timber for house construction, source of non timber products such as honey, spices and *Rhamnus prinoides*. It was also mentioned that the forest is serving as important source water for the communities. Some individuals also benefit from employment in OFWE and CCNP as guard/scout. The local people were claimed that the natural forest cover in the study area was decreased comparing to the condition of 30 years ago.

There was no direct involvement of community in forest ownership, management, and legal utilization of forest timber products. They suggested participatory or joint forest management as an option for better forest nagement.

4.7 Causes of LU/LC Changes

According to the data obtained from focus group discussions (FGDs) carried out in Tiro and Boter Becho, farmlands and settlement areas has been increasing from time to time because of growing population in the area. Oromia Forest and Wildlife Enterprise (OFWE), governmental owned enterprise, was engaged in production and sale of timber from plantations in Tiro and Boter Becho District Offices. The enterprise was planting seedlings of exotic plant species such as *Cupressus* and *Pinus* trees for commercial use. Timber was produced from these plant species to satisfy timber demand of the country.

Frequent fire hazard has been recognized in TBB as a factor that caused forest destruction in forest located at both higher and lower altitude of the study area taking forest fire incidents occurred in 2008 and 2012 as evidence. These fire incidences caused damage on natural forest. As forest fire in TBB was human induced element, effort has been made to distinguish the origin of the incident during the focus group discussion. They pointed out that honey collection in forest and sudden fire from farmlands was the main causes for forest fire incidence. The local communities living in the area adjacent to the forest are solely dependent on biomass energy for their energy source (for cooking and heating). As a result, they extract fuelwood and make charcoal from nearby forest. In addition, forest clearance for agricultural purpose, wood extraction, cutting of trees to extract honey, and debarking of few trees of *Ekebergia capensis* beehive fumigation, and cattle grazing inside the forest were observed (Figure 30 and 31).

Figure 30. Partial view of threat to the Afromontane forest of TBB

Based on data obtained during FGD carried out with local communities living adjacent to CCNP and KII with park authorities, settlements have taken place outside the park boundary (*i.e*. in 1996 and 2002 before the establishment of the park). This settlement resulted in increase in human population in the area, and now causing impacts on the park (farmland expansion, setting fire to the grass in the park, and hunting wild animals for food, hide, and Elephant tusks). During dry season, both natural and manmade fire was common phenomenon, taking place in the lowland areas of CCNP. Manmade fire was an intentional activity takes place almost every year to initiate the emergence of new grass for their livestock. Similar to communities in TBB, the local communities living adjacent to the forest in CCNP are solely dependent on biomass energy for their energy consumption in the form of fuel–wood and charcoal. In addition, it was observed that cattle are grazing inside the park. Trees were cut down for their timber and fuelwood, and small area of woodland in the park was cleared for agriculture (Figure 31).

Figure 31. Partial view of threat to the Afromontane forest of CCNP

Efforts have been made by OFWE to conserve the remaining natural forest of Afromontane forest of TBB thorough nursery establishment, seedling plantation, and buffer zone establishment around to the natural forest (Figure 32).

Figure 32. Partial view Nursery site and plantation of *Cupresus* as a buffer to the natural forest in TBB

Similarly, some conservation measures were carried out to protect the forest and wild animals of the CCNP. Undertaking regular education (awareness creation) programs to people inside and around the park to improve attitude of the local people residing the CCNP could be mentioned as evidence. The park management has also started negotiation to voluntarily relocate people who are living inside the park.

CHAPTER FIVE

5. DISCUSSION

5.1 Floristic Diversity and Composition

Afromontane forests are home for wide range of plant species. Floristically the Afromontane forests of TBB and CCNP are rich in plant species. Several studies on Afromontane forests have been conducted in different parts of the country to determine the floristic composition and diversity of plant. Although comparison of the species richness in various studies using statistical analyses is not feasible due to differences in size of the forests, survey methods, and objectives of the study. However, the overall species richness of the forests may give a general impression of their floristic diversity (Tadesse Woldemariam, 2003). Hence, one can understand that, with 204 plant species, Afromontane forest of TBB excels other similar rainforests like Harenna forest in southeast Ethiopia (160 species; Kumlachew Yeshitila, 1997), Komto forest in east Wellega (180 species; Fekadu Gurmessa *et al.,* 2013), Guraferda in southwestern Ethiopia (196 species; Dereje Denu, 2007), Sigmo–Setema in southwestern Ethiopia (196 species; Alemu Abebe, 2007), and Gara Ades forest in southeastern Ethiopia (124 species; Uhlig and Uhlig, 1990). Whereas the Afromontane forest of TBB had lower species record than those reported for the vegetation of the Gambella region in southwestern Ethiopia. i.e. 220 species (Tesfaye Awas *et al*., 2001), Bonga forest in southwest Ethiopia (243 species; Ensermu Kelbessa and Teshome Soromessa (2008), and Yayu forest in southwest Ethiopia (220 species; Tadesse Woldemariam *et al*., 2008). However, floristically, the Afromontane forest of CCNP had lower species record than the Afromontane forests mentioned earlier.

From plant families recorded in the study area, family Asteraceae had the highest species record compared to other families in the study areas. This might be due to the evolutionary characteristics of the family. It is known that family Asteraceae is an exceedingly large and widespread family of flowering plants. It exhibit extensive morphological and ecological diversity. Asteraceae was the family with highest number of species in studies of Ermias Lulekal *et al*. (2008) and Haile Yineger *et al*. (2008). Regarding habits of species identified, largest number of species was described as tree/shrub, followed by herbs, trees and shrubs. Whereas in CCNP, shrubs were the highest followed by herbs.

Afromontane rain forests of Ethiopia are known to be home for various endemic and indigenous plant species (Mesfin Tadesse, 1991). In addition to the diversity in plant species, the Afromontane forests of TBB and CCNP are important forests with respect to their endemicity. Comparing the endemicity to Dry Afromontane forests and other Moist Afromontane forests in Ethiopia, 29 endemic species were recorded at Wof–Washa forest (Demel Teketay and Tamrat Bekele, 1995), 14 endemic species were recorded at Sheko forest (Feyera Senbeta *et al*., 2007), 17 endemic species were recorded at Harenna forest, 14 endemic species were recorded at Berhane–Kontir, 14 endemic species were recorded at Bonga, 7 endemic species were recorded at Yayu, and 4 endemic species were recorded at Maji (Feyera Senbeta, 2006). The current study areas have 12 and 6 endemic plant species respectively.

Compared to endemicity to above mentioned forests, TBB had more endemic plant species than Maji, Yayu and CCNP. Whereas the Afromontane forest of CCNP had more endemic plant species diversity than Maji forest. The Afromontane forest of TBB had less endemic plant species diversity when compared to Wofwasha, Harenna, Bonga, Berhane–Kontir and Sheko forests. Similarly, the Afromontane forest of CCNP had less endemic plant species than Wofwasha, Harenna, Bonga, Berhane–Kontir, Yayu and Sheko forests. Friis *et al*. (2001) described that, low diversity of endemic plant species is a common feature of moist montane rain forests of southwest Ethiopia. Endemism is high in dry Afromontane forests and grassland complex than moist Afromontane forests (Sebsebe Demissew *et al*., 1996). Low endemicity in a given forest also associated to low diversity of environmental gradients and associated vegetation isolation (Kruckeberg and Rabinowitz, 1985).

5.2 Plant Community Structure

Plant species tend to occur together share certain environmental requirements (Keddy, 1982; Snow and Vince, 1984; Ellison *et al.*, 2000). Variations in environmental conditions of the area might to be responsible for plant species richness and changes in plant species composition of vegetation. In cluster analysis, five and three plant communities were identified in TBB and CCNP respectively.

Plant communities are collections of the plant species that are growing together in a particular location and show definite association or affinity with each other (Kent and Cooker, 1992). According to Snow and Vince (1984), distribution of plant species along environmental gradient arises as a result of physiological restriction of species to different portion of gradients. Environmental variables show strong correlation with species performance in some areas and none in others depending on a change in the limiting factor for plant growth or altering the correlation of the limiting factor with other environmental variables. Accordingly, from RDA analysis, the constraining variable highly correlated with axis one in TBB was potassium. Silt and Organic Carbon to a lesser extent were correlated to axis one. In CCNP, Elevation was the most constraining variable followed by Phosphorus and pH. Among the constraining variables, Potassium and Elevation in particular, contributed significantly in explaining pattern of variation in the species distribution and type of plant community formation in TBB and CCNP respectively. Potassium might have a major impact on plant growth through certain physio–chemical processes. Whereas, elevation might alters the correlation of the limiting factor with other environmental variables. Tadesse Woldemariam (2003) has found that, environmental factors such as altitude, slope, and landforms characterized the communities in Yayu forest. One important measure of the structural heterogeneity of a community is its diversity. Diversity in a community can be expressed in terms of number (richness) of species, degree of dominance by one or a few species, relative abundance of all species (evenness), number of rare species, vertical stratification of species, horizontal patchiness, number of growth or life forms, and so on.

Diversity measurements are used to interpret mechanisms operating in the community. High diversity in a given forest enhances community stability, community productivity and maintains niche structure (McIntosh, 1967). Accordingly, community 4 in TBB had highest diversity compared to the other four communities. Whereas community 5 had the least diversity compared to the other four communities. Similarly, community 1 in CCNP had the highest diversity than the other two communities, and community 3 had the least diversity. In TBB, community 5 was known by its lowest species richness. This might be due to its existence at highest elevated area. Habitats with extreme environmental conditions generally support few species and relatively few individuals of a species (Putman, 1994). The area where community 5 is located was highly affected by humans, so that the level of disturbance in that particular area was found to be high.

5.3 Population Structure

The general pattern of plant population structure that was emerged at both TBB and CCNP is an inverted – J shape, which had higher stems in the lower size classes and few individuals in the higher size classes. Afromontane forests studied by Tamrat Bekele (1993), Feyera Senbeta (2006), and Abreham Assefa *et al.* (2014) also showed inverted – J shape pattern of population structure. This pattern of plant population structure is an indication of a normal population distribution (Tamrat Bekele, 1993; Feyera Senbeta, 2006; Feyera Senbeta *et al*., 2007). However, the general pattern of a population structure is a cumulative result of all woody plants subjected to DBH and height measurement.

Various major types of patterns of plant population structure were identified at the Afromontane forests of TBB and CCNP. From these patterns, inverted J – shaped patterns show healthy regeneration pattern, where higher densities available at lower DBH and height classes followed by gradual decrease in densities to the higher DBH and height class. This kind of pattern with respect to DBH was exhibited by *Podocarpus falcatus*. The reason for the this kind of pattern might be due to the consumption of those woody species at the middle and higher DBH and height classes by local communities for various purposes. In the pattern of population structure represented by *Olea capensis* subsp. *macrocarpa*, the density if woody species at the first DBH class is lower than the second DBH class. It further gradually reduced to the tenth DBH class. In this pattern selective cutting at the first DBH class and between DBH class four and ten there might also be carried out. However, in the third pattern, which is represented by *Macaranga capensis*, zigzag pattern was observed indicating that no uniform variation at each DBH classes. This plant was seen to be consumed by browsers and also collected by the local people for firewood. In CCNP, *Syzygium guineense* stands from fivth to tenth DBH classes were expected to be logged for its timber value. the situation to *Prunus africana* in TBB is more serious than other plant species. this is because higher density was observed only at the first and last DBH classes forming a U – shapped pattern of population structure. *Prunus africana* is known by its timber quality in the area.

Generally, most population structures for specific plant species do not investigate a healthy structure for the fact that there might be selective logging at a particular DBH class. The probable effect on one species in a given DBH class might be compensated by another species when the entire forest is considered for population structure. Hence, it would be difficult to evaluate healthiness of a forest by only looking at the entire population structure without considering the population structure of some major plant species.

Diversity, Density and Basal Area of Vegetation

Diversity can be measured using one or more indices combining species richness and relative abundance within an area. Richness and diversity have commonly been described as a characteristic property of a putative homogeneous community and indicative of its organization (Macintosh, 1967). The two study areas had high diversity (H') of 3.45 for TBB and 3.32 for CCNP. This might be associated with the protection and conservation efforts made by OFWE in BB and the Park in CCNP. However, TBB had highest species richness compared to CCNP. This might be due to the existence of larger area coverage of Afromontane forest in TBB compared to CCNP. The second reason for higher diversity in TBB might be due to the fact that the forest is located adjacent to Central highlands of Ethiopia and shares some species with its neighboring Dry afromontane forests to the eastern side of the forest.

Total density of woody species encountered in TBB and CCNP was 1902 stems.ha^{-1} and 1562 stems.ha^{-1} respectively. Comparisons of densities for DBH > 10 cm and DBH > 20 cm of the Afromontane forests of TBB and CCNP along with other Afromontane forests of the country are given in Table 27 to identify proportion of small–sized to large–sized individuals in those forests. Pattern of density distribution of vegetation might be altered by one or more major environmental factors (Kershaw, 1973). The ratio of DBH > 10 cm to DBH > 20 cm was 1.9 for TBB and 2.1 for CCNP, which indicates slight variability of proportion between small–sized and large–sized individuals. The comparison of density of the present study areas with Afromontane forests of the central plateau of Shewa (Tamrat Bekele, 1993) and Masha–Anderacha forest (Kumelachew Yeshitela and Taye Bekele, 2003) showed that, TBB and CCNP were the first and the fourth respectively in density of woody species with DBH > 10 cm and the first and the third respectively in density of woody species with DBH > 20 cm. Like Chilimo and Menagesha forests and Masha–Anderacha forest, the ratio of density of species with DBH > 10cm to DBH > 20cm was very high indicating the predominance of small sized tree individuals. The former two forests, described by Tamrat Bekele (1993), were subjected to excessive cutting took place long time ago. But in Masha–Anderacha forest this was due to high density of *Cyathea maniana*. The situation in Both TBB and CCNP was due to high density of *Dracaena afromontana* and *Chionanthus mildbraedii*, small sized woody species in the forest.

Table 27. The ratio of tree densities of DBH > 10 cm and DBH > 20 cm at the Afromontane forests of TBB, CCNP and other selected Afromontane forests

Forest	DBH > 10 cm (a)	DBH > 20 cm (b)	a/b
Chilimo forest[a]	638	250	2.6
Menagesha forest[a]	484	208	2.3
Wof–Washa forest[a]	329	215	1.5
Masha forest[b]	633	286	2.2
TBB	678	366	1.9
CCNP	570	269	2.1

[a]Tamrat Bekele (1993); [b] Abreham Assefa (2009)

In contrast to simple count, basal area provides a better measure of the relative importance of woody species (Cain and Castro, 1959). According to Tamrat Bekele (1993), species with higher measure of basal area have higher contribution to the total basal area of a forest. Thus, these species can be considered as the most important species in a forest. In Afromontane forest of TBB, 69% of the total basal area was contributed by nine woody species. Those plant species which had much contributed for the total basal area in TBB are *Syzygium guineense* subsp. *afromontana*, *Olea capensis* subsp. *macrocarpa, Pouteria adolfi-friederici, Schefflera abyssinica, Macaranga capensis, Olinia rochetiana, Ficus sur, Podocarpus falcatus* and *Croton macrostachyus*. Similarly, nine woody species, namely: *Syzygium guineense* subsp. *afromontanum, Schefflera abyssinica, Prunus africana, Ficus sur, Ilex mitis, Pouteria adolfi–friederici, Schefflera volkensii, Olea capensis* subsp. *macrocarpa,* and *Apodytes dimidiata* contributed for 73% of the total basal area of the Afromontane forest of CCNP. Species which have greater contribution to the total basal of a given forest are considered as the most important species for that particular forest (Abreham Assefa *et al.*, 2014).

Gradual increase in basal area as increase in DBH class was seen from the Afromontane forests of TBB and CCNP. The highest basal area was obtained from plant species at DBH class 11. Most of trees at the Afromontane forests of TBB and CCNP were small sized. However, trees belonging to DBH class 11 (DBH higher than 50 cm) were fewer, but contribute much to the total basal area. For those woody plant species which are represented by few individuals (low density), recruitments and contribution of density for that particular DBH class was very low.

Comparison of basal area and densities in diameter classes in the study area indicates that there were more individuals in the first diameter classes both in TBB and CCNP, though their contribution to the basal area was very low. Majority of trees in study areas were small sized. Trees belonging to the highest DBH-class were fewer in number/density. However, these trees in highest DBH-class contributed much to the total basal areas of forests under study.

The basal areas in the current two study areas are almost alike (72.98 for TBB and 73.81 for CCNP), and higher than basal areas of the forests of Chilimo (30.1 $m^2\ ha^{-1}$) and Menagesha (36.1 $m^2\ ha^{-1}$) (Tamrat Bekele, 1993). However, the basal areas are lower than Wof–Washa forest (101.8 $m^2\ ha^{-1}$) (Tamrat Bekele, 1993) and Masha forest (147 $m^2\ ha^{-1}$) (Abreham Assefa *et al.*, 2014). Low basal areas in the former two forests were due to the fact that these forests have been under heavy exploitation for their timber (Tamrat Bekele, 1993). On the other hand, the Wof–Washa forest had been free from such abuse.

Furthermore, comparison of the basal area and densities of the current study area with other Afromontane forests in Central Plateau of Ethiopia (Tamrat Bekele, 1993) and Masha–Anderacha forest (Kumelachew Yeshitela and Taye Bekele, 2003) (Table 28) revealed that, for trees with DBH higher than 10 cm the current study area had higher basal area than Masha–Anderacha, Jibat and Chilimo forest. For trees with DBH lower than 10 cm, the current study area had higher densities than Masha–Anderacha forests, but lower densities than Jibat, Chilimo and Menagesha forests. For trees with DBH between 10 and 20 cm, the current study area had higher densities than Jibat, and Menagesha, but lower densities than Chilimo and Masha–Anderacha forests. Similarly, for trees with DBH higher than 20 cm, the current study area had higher densities than Central Plateau forests and Masha–Anderacha forest, which could be attributed to the predominance of few species such as *Pouteria adolfi-friederici* in the current study area.

Table 28. Structural characteristics of the Afromontane forests of TBB, CCNP and other selected Afromontane forests in the country

Characteristic	Jibat Forest[a]	Chilimo Forest[a]	Menagesha Forest[a]	Masha–Anderacha Forest[b]	Masha Forest[c]	TBB	CCNP
Basal area DBH > 10 cm	47.5	27.3	32.4	65.2	139	70	71
Density DBH< 10 cm	1254	1606	2010	574	1048	1223	992
Density 10 cm < DBH < 20 cm	275	388	276	987.7	347	312	302
Density DBH > 20 cm	285	250	208	150.8	286	366	269

Source: [a]Tamrat Bekele (1993); [b] Kumelachew Yeshitela and Taye Bekele (2003), [c]Abreham Assefa (2009)

Important Value Indices (IVI)

It is difficult to make a census of all inhabitants of diversified natural vegetation and to discover the role of each species in a complicated ecosystem (Clarke, 1954). Such tasks require the combined efforts of several taxonomists and ecologists competent to deal with detailed studies of the inhabitants of specific habitats/area. Thus, ecological significance of a species in a forest is compared using Importance Value (IV) of a species (Lamprecht, 1989).

Olea capensis subsp. *macrocarpa*, *Syzygium guineense* subsp. *afromontanum* and *Pouteria adolfi–friederici* were the top three plant species at the Afromontane forest of TBB that are indexed with respect to their importance. Similarly, *Syzygium guineense* subsp. *afromontanum* and *Prunus africana* woody species that had higher importance to the Afromontane forest of CCNP. Only few species in both study areas had higher IVI value. Majority of species in both TBB and CCNP had importance value indices of less than 10 indicating that attention should be given to conserve those species.

Density of Seedling and Sapling

The regeneration of Afromontane forest of TBB and CCNP was found to be low comparing to the regeneration status of Sheko forest, Yayu forest, Godere forest, Belete–Gera forest, Bonga forest, Setema forest, Sigmo forest (Elias Taye and Getachew Berhan, 2002) and Masha forest (Abreham Assefa *et al*., 2014) (Table 29).

Table 29. Regeneration status of some selected montane forests

Montane forests	Regeneration densities (stems.ha^{-1})
Sheko forest [b]	7277
Yayu forest [b]	6818
Godere forest [b]	6676
Belete–Gera forest [b]	6630
Bonga forest [b]	5656
Setema forest [b]	5528
Sigmo forest [b]	5226
Masha forest [c]	5289
TBB	2294
CCNP	1761

Source: [b] Elias Taye and Getachew Berhan (2002), [c]Abreham Assefa *et al*. (2014)

Phytogeographical comparison

Most characteristic tree species of Afromontane rainforest (Friis, 1992) recorded from TBB and CCNP are *Pouteria adolfi-friederici, Prunus africana, Polyscias fulva, Dracaena afromontana,* and *Syzygium guineense* subsp. *afromontanum.* Comparison of species composition of the two study areas each other and with four other moist Afromontane forests in southwest Ethiopia was carried out using Sorenson's similarity index (Table 30 and Table 31).

Table 30. Phytogeographical Comparison of Afromontane forest of TBB (altitudinal range of 1682 – 2339 and mean annual rainfall 1431 mm) with other five similar Afromontane forests in southwest Ethiopia

Forest	Mean annual rainfall (mm)	Altitudinal range (m)	a	b	c	Ss
Agama[1]	1830	1700 – 2370	57	86	22	0.51
Belete[2]	1800-2300	1300 – 3000	56	87	29	0.49
Guraferda[3]	-		58	81	17	0.54
Komto[4]	2067	2100 – 2482	69	74	28	0.58
Masha[5]	2192	1700 – 2321	62	81	17	0.56
CCNP	2082	1682 – 2339	91	52	13	0.74

[1]Admassu Addi *et al.* (2016); [2]Kflay Gebrehiwot and Kitessa Hundera (2014); [3]Dereje Denu (2007); [4]Fekadu Gurmessa *et al.* (2012); and [5]Abreham Assefa *et al.* (2014)

Table 31. Phytogeographical Comparison of Afromontane forest of CCNP with other five similar Afromontane forests in southwest Ethiopia.

Forest	Mean annual rainfall (mm)	Altitudinal range (m)	a	B	c	Ss
Agama[1]	1830	1700 – 2370	55	49	24	0.60
Belete[2]	1800-2300	1300 – 3000	49	55	36	0.52
Guraferda[3]			57	47	54	0.53
Komto[4]	2067	2100 – 2482	63	41	34	0.63
Masha[5]	2192	1700 – 2321	64	40	15	0.70

[1]Admassu Addi *et al.* (2016); [2]Kflay Gebrehiwot and Kitessa Hundera (2014); [3]Dereje Denu (2007); [4]Fekadu Gurmessa *et al.* (2012); and [5]Abreham Assefa *et al.* (2014)

'a' is number of common species to forest under comparison, 'b' is number of species found in present study area, 'c' is number of species found in vegetation of other sites in comparison with present study area and ''Ss'' is Sorenson's similarity index.

As a result, the highest similarity was observed between the two forests under study than any other Afromontane forest under comparison. Both the range of altitude and geographical location of Afromontane forest of TBB are very similar to Afromontane forest of CCNP as stated in Abreham Assefa *et al.*, (2014). These two forests are belongs to Gibe–Omo watershed. The highest floristic similarity between these two forests might be due to environmental factors and/or their proximity.

Afromontane forest of TBB showed higher similarity to Komto followed by Masha and Guraferda forests. These forests are located in the same agro–climatic region and obtain high annual rainfall. The Afromontane forest of TBB showed the least similarity to Belete forest. Similarly, Afromontane forest of CCNP showed higher similarity to Masha followed by Agama and Komto. The Afromontane forest of CCNP showed the least similarity to Belete forest. The possible explanations for the overall low floristic similarities between the current study areas and Afromontane rainforests under comparison might be due to their distance, variation in geographical location, and environmental determinism. Relation between geographical distance and floristic similarity can largely be explained by the fact that environmental variables change with geographical distance, which lead to the floristic dissimilarity (Tuomisto *et al*., 2003).

5.4 LU/LC Changes at TBB and CCNP

LULC class in CCNP varies both in TBB and in CCNP in all the three study periods. The largest area of TBB and CCNP park were occupied by Forest woodlad and respectively. The area of forest cover in TBB increased from the year 1984 to 2000. This increase was due to the mass plantation events carried out several times in the period. However this forest cover was declined in 2015 as a result of harvesting of plantations by OFWE for timber production. The decrease in forest area was also associated with conversion of some forested area to farmland. Clearance of forested area particularly for timber resulted in envision of the cleared area by herbaceous cover and grasses, which led to increased grassland cover.

Agriculture and settlement was covering small area in 1984, which gradually increased in 2015 mainly as the expense of both forest and woodland. In CCNP, unlike other land use/land cover types, large area of Woodland was converted to grasslands, agricultural and settlement in all the three study period. Forest was the next land use/land cover type which was converted to Agriculture and settlement land use type. The area of conversion of woodland to grassland, agriculture and settlement became increased from the initial period to the last study period. This indicates that woodland was being harvested for timber and other wood products and the area was cleared for expansion of farmlands. Several people were settled at lower altitudinal areas within the park and its periphery than the highland areas.

Several LU/LC studies conducted in different parts of the country indicated the level of loss of natural vegetation cover, expansion of cultivated land and increase in land degradation occurred in the areas where these studies were conducted. Most studies conducted in Ethiopia indicated that LU/LC changes have resulted in undesirable biophysical and socioeconomic impacts. For instance decrease in shrub lands, forests and riverine vegetation was reported to have occurred in Kalu area of south Wollo (Ethiopia) between1958 and 1986 by Kebrom Tekle and Hedlund (2000), substantial increase of cultivated lands between 1957 and 1995 was reported in Dembecha area, northwestern Ethiopia by Gete Zeleke (2000), remarkable increase of grassland at the cost of cropland and bare land was reported to have occurred in Beressa watershed, central highlands of Ethiopia, between 1957 and 2000 by Aklilu Amsalu (2006), a considerable loss of wetland, forest, grass and shrubland was reported to have occurred in Alemaya area of eastern Ethiopia between 1965 and 2007 by Mohammed Assen (2011). On the other hand, study conducted by Woldeamlak Bewket (2003) showed an increase in forestland in Chemoga watershed northwestern highlands of Ethiopia between 1957 and 1998. Study conducted by Asmamaw Legesse *et al.*, (2011) also showed the increase in forestland in Gerado catchment of northeastern Ethiopia between 1958 and 2006.

The overall pattern of LU/LC change at TBB and CCNP show that there was decrease in the vegetation cover (forest and woodland), while area cover of Agriculture and Settlement have progressively increased from the year 1984 to 2015. Whereas forest cover in CCNP showed small change when compared to woodland, grassland and agriculture. In CCNP, the establishment of the park and associated activities such as relocation/resettlement of some settlers inside the park and adjacent to it, recruitment of guards/scouts, and frequent awareness raising programs might have reduced the conversion of forest into other land use/land cover type. for In addition, some people living inside CCNP (in both lowland and highland areas) were found to convert forested areas in to agricultural land as a result of high demand of agricultural production due to increasing population over time. There was high rate of change of forest cover in TBB between the year 2000 and 2015 compared to other land use/land cover types. Following forest there was high rate change of woodland cover between the year 1984 and 2015. Similarly, there was high rate of conversion of woodland cover into other land use/land cover types in CCNP between the year 2000 and 2015.

Factors Contributing for LU/LC Changes at TBB and CCNP

Similar to other parts of the country, agriculture was reported as the main source of income to the local communities in both TBB and CCNP. Because of increase in population, households living in forested areas need more land for agricultural production. These demands were being satisfied through conversion of forest or woodland into agricultural lands. The forests were benefiting local communities in several ways. The forest serve as source of firewood, timber for house construction, source of non timber products, and source of water. In addition, both OFWE and CCNP were serving the communities by creating job opportunity to the local communities.

Study of LU/LC change at local scales is important to understand drivers of the changes and seek for viable land management options. Drivers of LU/LC change and level of influence by drivers of change vary in space and time depending on location–specific factors (Qasim *et al.*, 2013). The result of LU/LC changes at both TBB and CCNP implies that there might be some sort of socioeconomic changes taken place between the year 1984 and 2015 that altered the LU/LC of those areas. Results from focus group discussions showed that population pressure, poverty, timber production, firewood collection and charcoal making, and fire were the major causes for the LU/LC change in the two study areas. Cattle grazing inside the forest might result in trampling and browsing of seedlings and saplings of some plant species. Studies carried out in different parts of Ethiopia also have similar findings for the contribution of LU/LC changes. For instance, in Kebrom Tekle and Hedlund (2000), Woldeamlak Bewket (2002), Belay Tegene (2002) and Messay Mulugeta (2011), population increase, expansion of farmlands, fuel wood collection, charcoal making, and expansion of settlements were reported to be the major factors of LU/LC changes in various parts of Ethiopia. In Aklilu Amsalu (2006), Fikir Alemayehu *et al*. (2009), Gete Zeleke and Hurni (2001) and Hurni (1993), population pressure was indicated to be the largest factor causing LU/LC changes in many parts of Ethiopia. Population growth in the current study areas depicted that pressure on the land resources was high in the area, which in turn could have claimed more agricultural and settlement land and fuel wood consumption. This has led to the expansion of cultivated and settlement lands. Expansion of agricultural land and increase in settlements areas are an apparent indicators of impacts of a continuous increase in population density on the LU/LC of the area.

Conversion of other LU/LC for fresh agriculture has been takes place as the farmland become less productive, which caused expansion of cultivated lands. Thus, high dependence of the local community on agriculture caused LU/LC changes in the study area. Due to tree plantation and timber production at TBB by OFWE, the LU/LC was changing from grass/shrub land to shrub land and then to forest and back to shrub land after the forest has been harvested. Expansion of settlements in the area was also being carried out in the expense of forest. This finding is similar to the finding by Aerts *et al*. (2009). However, increase in forest cover in TBB was mainly associated to trees planted for timber production by OFWE.

Lack of community involvement in forest management was mentioned as one of the cause for forest degradation. Community based forest management or joint forest management approach were the options raised by the communities as an option for sustainable forest management.

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Afromontane forests of TBB and CCNP are diverse with respect to their species composition and existence of several endemic plant species. The overall population structure forest in the two study areas have similar pattern showing healthy regeneration pattern. Similarly, the plant communities identified at the two study sites also showed the same pattern as the population structure does. In contrary, the two forests are threatened as a result of human activities demanding the existing forest recourses. Dealing with the healthiness of the regeneration pattern of a forest by looking at the overall population structure as well as description of structures of plant communities identified from that forest would be misleading. Because, some species are highly threatened than the other and the effect was compensated by another species that are not under threat.

These Moist Afromontane forests are home for emergent trees species such as *Pouteria adolfi-friedrici*, *Olea welwitschii*, and *Prunus africanus*. However, these plant species are under severe threat as a result of selective logging and grazing taking place inside the forest. In addition, the overall regeneration status (*i.e*. seedling and sapling) of the forests can be taken as poor, so that it needs attention for conservation. Different environmental variables are responsible for distribution and assemblage of plants in different area/forest. Due to the existence of high density of *Pouteria adolfi-friederici* at the Afromontane forest of TBB, the area can be taken as an *in-situ* conservation site in the for *Pouteria adolfi-friederici.* This in turn helps to conserve the gene pool of other species in the area and maintain plant communities with high species diversity.

The local communities of the forested areas of the two study areas were mainly dependent on agriculture. They also rely on the forest resources various uses. LU/LC of the two study areas were changing from time to time. Decrease in vegetation cover and increase in agriculture and settlement in the study area is an indication of conversion of forest and other land use types because of demand for land for agriculture and settlement. The change from reduction of more natural vegetation (natural forest and woodland) to expanded cultivated land was more of conversion and high change of this type was observed between 2000 and 2015. This change might alter both ecological and economical values of the Afromontane forests of the study areas, and Gibe–Omo watershed subsequently.

OFWE and CCNP were serving as the main actors of the protection and conservation of natural resources especially forest resources in the respective study areas. However, due to rapid population growth, resulted in increase in Agriculture and settlement cover and contributed for decrease in forest and woodland cover. The existing forest management system in the area was not allowing the local communities in management and utilization of the forest resources owned by the government. This situation was contributed for the conversion of the forest and woodlands into other land use/land cover types.

6.2 Recommendations

To maintain ecological and economical benefit of the Afromontane forests of TBB and CCNP, the government should allow the local communities to involve in conservation, management, and utilization (as participatory or joint forest management) for sustainable management of the existing forests. This will in turn help to conserve the gene pool of those plant species under threat and maintain original plant community with large species diversity.

The concerning bodies such as local governments and the Ministry of Environment, Forest and Climate Change (MEFCC) in collaboration of Ministry of Agriculture and Natural Resource should introduce alternative means of income generation to avoid further conversion of forest to other land use/land cover type. The management options should include reducing livestock pressure on forest, limiting further expansion of farmlands and providing farmers/community with tree species as alternative to their wood/timber need. Introduction of participatory forest management will allow the local communities living around the forest to participate in forest management for a better conservation and utilization of the resources in the area.

In addition, the local communities should be supported to increase household income through certain activities such as agricultural intensification and improved (or SMART) agricultural practices, and off–farm economic activities. In addition, improve the use of modern stoves for efficient energy consumption might help the sustainability of natural forest. Moreover, effective enforcement of forest laws/policies should also be there.

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ANNEXES

Annex 1. List of plant species recorded at the Afromontane forests of TBB and CCNP

S. No	Scientific Name	Family	Habit	TBB	CCNP
1	*Abutilon longicuspe* Hochst. ex A. Rich.	Malvaceae	H/Sh	✓	✓
2	*Acalypha psilostachya* Hochst.	Euphorbiaceae	H/Sh	✓	
3	*Acanthopale pubescens* (Lindau ex Engl.) C.B. Clarke	Acanthaceae	H	✓	✓
4	*Acanthus eminens* C. B. Clarke	Acanthaceae	Sh	✓	✓
5	*Acanthus sennii* Chiov.	Acanthaceae	Sh	✓	
6	*Achyranthes aspera* L.	Amaranthaceae	H	✓	✓
7	*Achyrospermum schimperi* (Hochst. ex Briq.) Perkins	Lamiaceae	H/Sh		✓
8	*Adenostemma mauritianum* DC.	Asteraceae	H		✓
9	*Adiantum thalictroides* Wild.	Adiantaceae	F	✓	
10	*Aframomum corrorima* (Braun) Jansen	Zingeberaceae	H		✓
11	*Agarista salicifolia* (Comm. ex Lam.) Hook.	Ericaceae	T/Sh		✓
12	*Ageratum conyzoides* L.	Asteraceae	H		✓
13	*Albizia gummifera* (J. F. Gmel.) C. A. Sm	Fabaceae	T	✓	✓
14	*Albizia schimperiana* Oliv.	Fabaceae	T	✓	✓
15	*Alchemilla abyssinica* Fresen.	Rosaceae	H	✓	
16	*Alchemilla pedata* A. Rich.	Rosaceae	H	✓	✓
17	*Allophylus abyssinicus* (Hochst.) Radlkofer	Sapindaceae	T	✓	✓
18	*Anthemis tigreensis* J.Gay ex A. Rich.	Asteraceae	H	✓	
19	*Apodytes dimidiata* E. Mey. ex Arn.	Icacinaceae	T	✓	✓
20	*Aristea abyssinica* Pax	Iridaceae	H	✓	

S. No	Scientific Name	Family	Habit	TBB	CCNP
21	*Arundinaria alpina* K. Schum.	Poaceae	T	✓	✓
22	*Asparagus africanus* Lam.	Asparagaceae	Sh/Li	✓	✓
23	*Aspilia mossambicensis* (Oliv.) Wild	Asteraceae	H/Sh	✓	
24	*Asystasia mysorensi* (Roth) T. Anders.	Acanthaceae	H	✓	
25	*Athrixia rosmarinifolia* (Sch. Bip. ex Walp.) Oliv. & Hiern	Asteraceae	H/Sh	✓	
26	*Cyperus dereilema* Steud.	Cyperaceae	H	✓	✓
27	*Barleria ventricosa* Hochst. ex Nees	Acanthaceae	H	✓	
28	*Bersama abyssinica* Fresen.	Melianthaceae	T/Sh	✓	✓
29	*Brucea antidysenterica* J. F. Mill.	Simarubaceae	T/Sh	✓	✓
30	*Buddleja polystachya* Fresen.	Loganiaceae	T/Sh		✓
31	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	T/Sh	✓	✓
32	*Canthium oligocarpum* Hiern	Rubiaceae	T/Sh	✓	✓
33	*Carduus leptacanthus* Fresen.	Asteraceae	H		✓
34	*Carissa spinarum* L.	Apocynaceae	Sh/Li	✓	✓
35	*Cassipourea malosana* (Baker) Alston	Rhizophoraceae	T	✓	✓
36	*Celtis africana* Burm. f.	Ulmaceae	T	✓	✓
37	*Chionanthus mildbraedii* (Gig & Schellenb.) Stearn	Oleaceae	T/Sh	✓	✓
38	*Cirsium vulgare* (Savi.) Ten.	Asteraceae	H	✓	
39	*Cissampelos pareira* L.	Menispermaceae	Li	✓	
40	*Clausena anisata* (Willd.) Benth.	Rutaceae	T/Sh	✓	✓
41	*Clematis hirsuta* Perro & Guill	Ranunculaceae	Sh		✓
42	*Clematis longicauda* Steud.ex A. Rich.	Ranunculaceae	Cl	✓	✓
43	*Clematis simensis* Fresen.	Ranunculaceae	Li	✓	✓
44	*Clerodendrum myricoides* (Hochst.) Vatke	Lamiaceae	H/Sh		✓

S. No	Scientific Name	Family	Habit	TBB	CCNP
45	*Clutia abyssinica* Jaub. & Spach.	Euphorbiaceae	H/Sh	✓	✓
46	*Coffea arabica* L.	Rubiaceae	T/Sh		✓
47	*Combretum paniculatum* Vent.	Combretaceae	Sh/Li	✓	✓
48	*Commelina foliacea* Chiov.	Commelinaceae	H		✓
49	*Conyza hypoleuca* A. Rich	Asteraceae	T/Sh	✓	
50	*Cordia africana* Lam.	Boraginaceae	T		✓
51	*Crepis rueppellii* Sch. Bip.	Asteraceae	H	✓	
52	*Crotalaria alexandri* Bak. f.	Fabaceae	H	✓	✓
53	*Croton macrostachyus* Del.	Euphorbiaceae	T/Sh	✓	✓
54	*Cyathea manniana* Hook.	Cyatheaceae	T		✓
55	*Cyathula cylindrica* Moq.	Amaranthaceae	H	✓	
56	*Cynoglossum amplifolium* Hochst. ex A. DC. in DC.	Boraginaceae	H	✓	✓
57	*Cynoglossum lanceolatum* Forssk.	Boraginaceae	H	✓	
58	*Cyperus fischerianus* A. Rich.	Cyperaceae	H	✓	✓
59	*Cyphostemma adenocaule* (Steud. ex A. Rich.) Descoings ex Wild & Drummond	Vitaceae	Cl	✓	✓
60	*Cyphostemma cyphopetalum* (Fresen.) Descoings ex Wild & Drummond	Vitaceae	Cl	✓	
61	*Desmodium repandum* (Vahl) DC.	Fabaceae	H/Sh	✓	✓
62	*Dicliptera laxata* C. B. Clarke	Acanthaceae	H	✓	
63	*Discopodium penninervium* Hochst.	Solanaceae	T	✓	
64	*Dissotis senegambiensis* (GuilL. & Perr.) Triana	Melastomataceae	H		✓
65	*Dodonaea angustifolia* L. f.	Sapindaceae	Sh	✓	✓
66	*Dombeya torrida* (J. F. Gmel.) P. Bamps	Sterculariaceae	T	✓	✓
67	*Dovyalis abyssinica* (A. Rich.) Warb	Flacourtiaceae	T/Sh	✓	
68	*Dovyalis verrucosa* (Hochat.) Warb.	Flacourtiaceae	T/Sh	✓	

S. No	Scientific Name	Family	Habit	TBB	CCNP
69	*Dracaena afromontana* Mildbr.	Dracaenaceae	T/Sh	✓	✓
70	*Dracaena steudneri* Engl.	Dracaenaceae	T/Sh	✓	✓
71	*Dumasia villosa* DC.	Fabaceae	Cl	✓	✓
72	*Ehretia cymosa* Thonn.	Boraginaceae	T/Sh	✓	✓
73	*Ekebergia capensis* Spamn.	Meliaceae	T	✓	✓
74	*Elaeodendron buchananii* (Loes.) Loes.	Celastraceae	T/Sh	✓	✓
75	*Embelia schimperi* Vatke	Myrsinaceae	Sh/Li/T	✓	✓
76	*Englerina woodfordioides* (Schweinf.) M. Gilbert	Loranthaceae	H	✓	
77	*Ensete ventricosum* (Welw.) Cheesman	Musaceae	H		✓
78	*Erica arborea* L.	Ericaceae	T/Sh	✓	
79	*Erythrina abyssinica* Lam. ex DC.	Fabaceae	T/Sh	✓	
80	*Erythrina brucei* Schweinf.	Fabaceae	T	✓	✓
81	*Erythrococca trichogyne* (Muell. Arg) Prain.	Euphorbiaceae	T/Sh	✓	✓
82	*Euphorbia schimperiana* Scheele	Euphorbiaceae	H		✓
83	*Ficus lutea* Vahl	Moraceae	T		✓
84	*Ficus sur* Forssk.	Moraceae	T	✓	✓
85	*Flacoutia indica* (Burm.f) Merr.	Flacourtiaceae	T/Sh	✓	✓
86	*Galiniera saxifraga* (Hochst.) Bridson	Rubiaceae	T/Sh	✓	✓
87	*Galium aparinoides* Forssk.	Rubiaceae	H	✓	
88	*Garcinia budlananii* Baker	Clusiaceae	T/Sh	✓	
89	*Geranium arabicum* Forssk.	Geraniaceae	H		✓
90	*Gomphocarpus semilunatus* A. Rich.	Asclepiadaceae	H/Sh	✓	
91	*Gouania longispicta* Engl.	Rhamnaceae	Sh/Li	✓	✓
92	*Guizotia scabra* (Vis.) Chiov.	Asteraceae	H	✓	

S. No	Scientific Name	Family	Habit	TBB	CCNP
93	*Hagenia abyssinica* (Bruce) J. F. Gmel.	Rosaceae	T	✓	✓
94	*Hebenstretia angolensis* Rolfe	Scrophulariaceae	H/Sh	✓	
95	*Helichrysum forsskahlii* (J. F. Gmel.) Hilliard & Burtt	Asteraceae	H	✓	
96	*Helichrysum splendidum* (Thunb.) Less.	Asteraceae	H/Sh	✓	
97	*Helinus mystacinus* (Ait.) E. Mey. ex Steud.	Rhamnaceae	Li	✓	
98	*Hibiscus macranthus* Hochst. ex A. Rich.	Malvaceae	H/Sh	✓	
99	*Hippocratea africana* (Willd.) Loes.	Celastraceae	Sh/Li	✓	✓
100	*Hippocratea goetzei* Loes.	Celastraceae	Sh/Li	✓	✓
101	*Hydrocotyle mannii* Hook.f	Apiaceae	H		✓
102	*Hypericum peplidifolium* A. Rich.	Clusiaceae	H	✓	
103	*Hypericum quartinianum* A. Rich.	Clusiaceae	T/Sh	✓	✓
104	*Hypericum revolutum* Vahl.	Clusiaceae	T/Sh	✓	✓
105	*Hypoestes forskaolii* (Vahl) R. Br.	Acanthaceae	H	✓	✓
106	*Hypoestes triflora* (Forssk.) Roem & Schult.	Acanthaceae	H	✓	✓
107	*Ilex mitis* (L.) Radlk.	Aquifoliaceae	T/Sh	✓	✓
108	*Isoglossa somalensis* Lindau	Acanthaceae	Sh	✓	
109	*Jasminum abyssinicum* Hochst. ex DC.	Oleaceae	Li	✓	✓
110	*Juniperus procera* Hochst. ex Endl.	Cuppressaceae	T	✓	
111	*Justicia ladanoides* Lam.	Acanthaceae	H	✓	
112	*Justicia schimperiana* (Hochst. ex Nees) T. Anders.	Acanthaceae	Sh	✓	✓
113	*Kalanchoe petitiana* A. Rich.	Crassulaceae	H	✓	
114	*Kosteletzkya begoniifolia* (Ulbr.) Ulbr.	Malvaceae	H		✓
115	*Landolphia buchananii* (Hall. F.) Stapf	Apocynaceae	Sh/Li	✓	✓
116	*Leonotis ocymifolia* (Burm. f.) Iwarsson	Lamiaceae	Sh	✓	

S. No	Scientific Name	Family	Habit	TBB	CCNP
117	*Lepidotrichilia volkensii* (Gilrke) Leroy	Meliaceae	T	✓	✓
118	*Leucas deflexa* Hook. f.	Lamiaceae	H	✓	✓
119	*Leucas martinicensis* (Jacq.) R. Br.	Lamiaceae	H	✓	
120	*Lippia adoensis* Hochst. ex Walp.	Verbenaceae	Sh	✓	
121	*Lobelia giberroa* Hemsl.	Lobeliaceae	T/Sh		✓
122	*Macaranga capensis* (Baill.) Sim.	Euphorbiaceae	T	✓	✓
123	*Maesa lanceolata* Forssk.	Myrsinaceae	T/Sh	✓	✓
124	*Maytenus addat* (Loes.) Sebsebe	Celastraceae	T	✓	
125	*Maytenus arbutifolia* (A. Rich.) Wilczek	Celastraceae	T/Sh	✓	
126	*Maytenus gracilipes* (Welw. ex Oliv.) Exell subsp. *arguta* (Loes.) Sebsebe	Celastraceae	T/Sh	✓	✓
127	*Maytenus undata* (Thunb.) Blakelock	Celastraceae	T/Sh	✓	✓
128	*Micractis bojeri* DC	Asteraceae	H		✓
129	*Microglossa pyrifolia* (Lam.) Kuntze	Asteraceae	Sh	✓	✓
130	*Millettia ferruginea* (Hochst.) Bak. subsp. *darassana* (Cuf.) Gillett	Fabaceae	T	✓	✓
131	*Mimulopsis solmsii* Schweinf.	Acanthaceae	Sh	✓	✓
132	*Momordica foetida* Schumach.	Cucurbitaceae	Cl	✓	✓
133	*Monothecium glandulosum* Hochst.	Acanthaceae	H		✓
134	*Myrica salicifolia* A. Rich	Myricaceae	T/Sh	✓	✓
135	*Myrsine africana* L.	Myrsinaceae	T/Sh	✓	✓
136	*Myrsine melanophloes* (L.) R. Br.	Myrsinaceae	T/Sh	✓	✓
137	*Nuxia congesta* R. Br. ex Fresen.	Loganiaceae	T/Sh	✓	✓
138	*Ocimum lamiifolium* Hochst. ex Benth.	Lamiaceae	Sh	✓	
139	*Oldenlandia monanthos* L.	Rubiaceae	H	✓	
140	*Olea capensis* L. subsp. *macrocarpa* (C. H. Wright) Verdc.	Oleaceae	T	✓	✓

S. No	Scientific Name	Family	Habit	TBB	CCNP
141	*Olea europaea* L. subsp. *cuspidata* (Wall. ex G. Don) Cif	Oleaceae	T/Sh	✓	
142	*Olea welwitschii* (Knobl.) Gilg & Schellenb.	Oleaceae	T	✓	✓
143	*Olinia rochetiana* A. Juss.	Oliniaceae	T/Sh	✓	✓
144	*Oncoba spinosa* Forssk.	Flacourtiaceae	T/Sh	✓	✓
145	*Oplismenus hirtellus* (L.) P. Beauv.	Poaceae	G	✓	✓
146	*Osyris quadripartita* Decn.	Santalaceae	T/Sh	✓	
147	*Paveta abyssinica* Fresen.	Rubiaceae	T/Sh	✓	
148	*Pavonia kilimandscharica* Gürke	Malvaceae	Sh	✓	
149	*Pegolettia senegalensis* Cass.	Asteraceae	H	✓	
150	*Pennisetum thunbergii* Kunth	Poaceae	G	✓	
151	*Pentas lanceolata* (Forssk.) Deflers	Rubiaceae	H/Sh	✓	
152	*Pentas schimperiana* (A. Rich.) Vatke subsp. *schimperiana*	Rubiaceae	H/Sh	✓	
153	*Peperomia abyssinica* Miq.	Piperaceae	H		✓
154	*Peperomia molleri* C. DC.	Piperaceae	H	✓	
155	*Peperomia tetraphylla* (Forster) Hook. & Arn.	Piperaceae	H	✓	✓
156	*Peponium vogelii* (Hook.f) Engl.	Cucurbitaceae	Cl		✓
157	*Periploca linearifolia* Quart. –Dill. & A. Rich	Asclepiadaceae	Li	✓	✓
158	*Phoenix reclinata* Jacq.	Arecaceae	T	✓	✓
159	*Phyllanthus fischeri* Pax	Euphorbiaceae	H		✓
160	*Phyllanthus ovalifolius* Forssk.	Euphorbiaceae	T/Sh	✓	
161	*Phytolacca dodecandra* L'Herit	Phytolaccaceae	Sh	✓	✓
162	*Pilea bambuseti* Engl. subsp. *aethiopica* Friis	Urticaceae	H	✓	✓
163	*Piper capense* L.f.	Piperaceae	H		✓
164	*Pittosporum viridiflorum* Sims	Pittosporaceae	T/Sh	✓	✓

S. No	Scientific Name	Family	Habit	TBB	CCNP
165	*Plantago lanceolata* L.	Plantaginaceae	H	✓	
166	*Plantago palmata* Hook. f.	Plantaginaceae	H	✓	✓
167	*Plectocephalus varians* (A. Rich.) C. Jeffrey ex Cufod.	Asteraceae	H	✓	
168	*Plectranthus alpinus* (Vatke) Ryding	Lamiaceae	H	✓	
169	*Podocarpus falcatus* (Thunb.) R.B. ex Mirb.	Podocarpaceae	T	✓	
170	*Polyscias fulva* (Hiern) Harms	Araliaceae	T	✓	✓
171	*Pouteria adolfi–friederici* (Engl.) Baehni	Sapotaceae	T	✓	✓
172	*Premna schimperi* Engl.	Lamiaceae	T/Sh	✓	
173	*Prunus africana* (Hook. F.) Kalkm	Rosaceae	T	✓	✓
174	*Pseudognaphalium richardianum* (Cufod.) Hilliard & Burtt	Asteraceae	H	✓	
175	*Psychotria orophila* Petit	Rubiaceae	T/Sh	✓	✓
176	*Pteridium aquilinum* (L.) Kuhn	Dennstaedtiaceae	F	✓	✓
177	*Pteris cretica* L.	Pteridaceae	F	✓	✓
178	*Pteris pteroides* (Hook.)	Pteridaceae	F	✓	✓
179	*Pteris quadriaurita* Retz.	Pteridaceae	F	✓	
180	*Pycnostachys eminii* Gurke	Lamiaceae	H/Sh	✓	
181	*Rhamnus prinoides* L'Herit.	Rhamnaceae	T/Sh	✓	✓
182	*Rhus glutinosa* A. Rich.	Anacardiaceae	T/Sh	✓	✓
183	*Rhus vulgaris* Meikle	Anacardiaceae	T/Sh	✓	✓
184	*Ritchiea albersii* Gilg	Capparidaceae	T/Sh	✓	✓
185	*Rosa abyssinica* Lindley	Rosaceae	Sh/Li/T	✓	✓
186	*Rothmannia urcelliformis* (Hiern) Robyns	Rubiaceae	T/Sh		✓
187	*Rubus steudneri* Schweinf.	Rosaceae	Sh	✓	✓
188	*Rytigynia neglecta* (Hiern) Robyns	Rubiaceae	Sh	✓	✓

S. No	Scientific Name	Family	Habit	TBB	CCNP
189	*Salvia nilotica* Jacq.	Lamiaceae	H	✓	
190	*Sanicula elata* Buch.–Ham. ex D. Don	Apiaceae	H	✓	✓
191	*Sapium ellipticum* (Krauss) Pax	Euphorbiaceae	T/Sh	✓	
192	*Satureja punctata* (Benth.) Briq.	Lamiaceae	Sh	✓	
193	*Satureja simensis* (Benth.) Briq.	Lamiaceae	H	✓	
194	*Scabiosa columbaria* L.	Dipsacaceae	H	✓	
195	*Scadoxus multiflorus* (Martyn) Raf.	Amarylidaceae	H	✓	
196	*Schefflera abyssinica* (Hochst. ex. A. Rich) Harms	Araliaceae	T	✓	✓
197	*Schefflera volkensii* (Engl.) Harms	Araliaceae	Sh/Li/T	✓	✓
198	*Schrebera alata* (Hochst.) Welw.	Oleaceae	T/Sh	✓	✓
199	*Senna petersiana* (Bolle) Lock	Fabaceae	T/Sh	✓	
200	*Setaria megaphylla* (Steud.) Th. Dur. & Schinz	Poaceae	G	✓	
201	*Sida schimperiana* Hochst. ex A. Rich.	Malvaceae	Sh	✓	
202	*Smilax anceps* Willd	Smilacaceae	Li	✓	✓
203	*Smilax aspera* L.	Smilacaceae	Li	✓	✓
204	*Solanecio gigas* (Vatke) C. Jeffrey	Asteraceae	T/Sh	✓	
205	*Solanecio mannii* (Hook. f.) C. Jeffrey	Asteraceae	T/Sh	✓	✓
206	*Solanum anguivi* Lam.	Solanaceae	H		✓
207	*Solanum giganteum* Jacq.	Solanaceae	T/Sh	✓	
208	*Solanum nigrum* L.	Solanaceae	H	✓	
209	*Sonchus bipontini* Asch.	Asteraceae	H	✓	
210	*Sonchus oleraceus* L.	Asteraceae	H	✓	
211	*Sparmannia ricinocarpa* Eckl. & Zeyh.) O. Ktze.	Tiliaceae	Sh	✓	
212	*Stachys aculeolata* Hook.f	Lamiaceae	Cl	✓	

S. No	Scientific Name	Family	Habit	TBB	CCNP
213	*Stephania abyssinica* (Dillon & A. Rich.) Walp.	Menispermaceae	H	✓	✓
214	*Streblochaete longiarista* (A. Rich.) Pilg.	Poaceae	G	✓	
215	*Swertia tetrandra* Hochst.	Gentianaceae	H	✓	
216	*Syzygium guineense* (Wild.) DC. subsp. *afromontanum* F. White	Myrtaceae	T	✓	✓
217	*Tacazzea apiculata* Oliv.	Asclepiadaceae	Li	✓	
218	*Tacazzea conferta* N. E. Br.	Asclepiadaceae	Li	✓	✓
219	*Tapinanthus heteromorphus* (A. Rich.) Danser	Loranthaceae	Sh	✓	
220	*Teclea nobilis* Del.	Rutaceae	T/Sh	✓	✓
221	*Tephrosia interrupta* Hoechst. & Steud ex Engl.	Fabaceae	H/Sh	✓	
222	*Tiliachora troupinii* Cufod.	Menispermaceae	Li	✓	✓
223	*Toddalia asiatica* (L.) Lam.	Rutaceae	H	✓	✓
224	*Tragia brevipes* Pax	Euphorbiaceae	H/Sh	✓	
225	*Trema orientalis* (L.) Bl.	Ulmaceae	T/Sh	✓	✓
226	*Trichilia dregena* Sond.	Meliaceae	T	✓	
227	*Triumfetta brachyceras* K. Schum.	Tiliaceae	H/Sh	✓	✓
228	*Triumfetta rhomboidea* Jacq.	Tiliaceae	H	✓	
229	*Turraea holstii* Gurke	Meliaceae	T/Sh	✓	
230	*Urera hypselodendron* (A. Rich.) Weed.	Urticaceae	Li		✓
231	*Vepris dainellii* (Pichi–serm.) Kokwaro	Rutaceae	T/Sh	✓	✓
232	*Verbascum sinaiticum* Benth.	Scrophulariaceae	H	✓	
233	*Vernonia amygdalina* Del.	Asteraceae	T/Sh	✓	✓
234	*Vernonia bipontini* Vatke	Asteraceae	H/Sh	✓	

Annex 2. List of plant families with their number of genera and species encountered at the afromontane forest of TBB

Family	No. of Species	%	No. of Genera	%
Asteraceae	19	9.31	15	9.04
Acanthaceae	12	5.88	9	5.42
Fabaceae	11	5.39	9	5.42
Lamiaceae	11	5.39	9	5.42
Rubiaceae	9	4.41	8	4.82
Euphorbiaceae	8	3.92	8	4.82
Celastraceae	7	3.43	3	1.81
Oleaceae	6	2.94	4	2.41
Rosaceae	6	2.94	5	3.01
Poaceae	5	2.45	5	3.01
Asclepiadaceae	4	1.96	3	1.81
Clusiaceae	4	1.96	2	1.20
Flacourtiaceae	4	1.96	3	1.81
Malvaceae	4	1.96	4	2.41
Meliaceae	4	1.96	4	2.41
Myrsinaceae	4	1.96	3	1.81
Rutaceae	4	1.96	4	2.41
Araliaceae	3	1.47	2	1.20
Boraginaceae	3	1.47	2	1.20
Menispermaceae	3	1.47	3	1.81
Pteridaceae	3	1.47	1	0.60
Rhamnaceae	3	1.47	3	1.81
Solanaceae	3	1.47	2	1.20
Tiliaceae	3	1.47	2	1.20
Amaranthaceae	2	0.98	2	1.20
Anacardiaceae	2	0.98	1	0.60
Apocynaceae	2	0.98	2	1.20
Cyperaceae	2	0.98	1	0.60
Dracaenaceae	2	0.98	1	0.60
Loranthaceae	2	0.98	2	1.20
Piperaceae	2	0.98	1	0.60
Plantaginaceae	2	0.98	1	0.60
Ranunculaceae	2	0.98	1	0.60
Sapindaceae	2	0.98	2	1.20
Scrophulariaceae	2	0.98	2	1.20
Smilacaceae	2	0.98	1	0.60
Ulmaceae	2	0.98	2	1.20
Vitaceae	2	0.98	1	0.60
Adiantaceae	1	0.49	1	0.60

Family	No. of Species	%	No. of Genera	%
Amarylidaceae	1	0.49	1	0.60
Apiaceae	1	0.49	1	0.60
Aquifoliaceae	1	0.49	1	0.60
Arecaceae	1	0.49	1	0.60
Asparagaceae	1	0.49	1	0.60
Capparidaceae	1	0.49	1	0.60
Combretaceae	1	0.49	1	0.60
Crassulaceae	1	0.49	1	0.60
Cucurbitaceae	1	0.49	1	0.60
Cuppressaceae	1	0.49	1	0.60
Dennstaedtiaceae	1	0.49	1	0.60
Dipsacaceae	1	0.49	1	0.60
Ericaceae	1	0.49	1	0.60
Gentianaceae	1	0.49	1	0.60
Icacinaceae	1	0.49	1	0.60
Iridaceae	1	0.49	1	0.60
Loganiaceae	1	0.49	1	0.60
Melianthaceae	1	0.49	1	0.60
Moraceae	1	0.49	1	0.60
Myricaceae	1	0.49	1	0.60
Myrtaceae	1	0.49	1	0.60
Oliniaceae	1	0.49	1	0.60
Phytolaccaceae	1	0.49	1	0.60
Pittosporaceae	1	0.49	1	0.60
Podocarpaceae	1	0.49	1	0.60
Rhizophoraceae	1	0.49	1	0.60
Santalaceae	1	0.49	1	0.60
Sapotaceae	1	0.49	1	0.60
Simarubaceae	1	0.49	1	0.60
Sterculariaceae	1	0.49	1	0.60
Urticaceae	1	0.49	1	0.60
Verbenaceae	1	0.49	1	0.60

Annex 3. List of plant families with their number of genera and species encountered at the afromontane forest of CCNP

Family	No. of Species	%	No. of Genera	%
Fabaceae	8	5.56	7	5.51
Acanthaceae	7	4.86	6	4.72
Asteraceae	7	4.86	7	5.51
Euphorbiaceae	6	4.17	6	4.72
Rubiaceae	6	4.17	6	4.72
Celastraceae	5	3.47	3	2.36
Oleaceae	5	3.47	4	3.15
Rosaceae	5	3.47	5	3.94
Myrsinaceae	4	2.78	3	2.36
Rutaceae	4	2.78	4	3.15
Araliaceae	3	2.08	2	1.57
Boraginaceae	3	2.08	3	2.36
Lamiaceae	3	2.08	3	2.36
Piperaceae	3	2.08	2	1.57
Ranunculaceae	3	2.08	1	0.79
Anacardiaceae	2	1.39	1	0.79
Apiaceae	2	1.39	2	1.57
Apocynaceae	2	1.39	2	1.57
Asclepiadaceae	2	1.39	2	1.57
Clusiaceae	2	1.39	1	0.79
Cucurbitaceae	2	1.39	2	1.57
Cyperaceae	2	1.39	1	0.79
Dracaenaceae	2	1.39	1	0.79
Flacourtiaceae	2	1.39	2	1.57
Loganiaceae	2	1.39	2	1.57
Malvaceae	2	1.39	2	1.57
Meliaceae	2	1.39	2	1.57
Menispermaceae	2	1.39	2	1.57
Moraceae	2	1.39	1	0.79
Poaceae	2	1.39	2	1.57
Pteridaceae	2	1.39	1	0.79
Rhamnaceae	2	1.39	2	1.57
Sapindaceae	2	1.39	2	1.57
Smilacaceae	2	1.39	1	0.79
Ulmaceae	2	1.39	2	1.57
Urticaceae	2	1.39	2	1.57
Amaranthaceae	1	0.69	1	0.79
Aquifoliaceae	1	0.69	1	0.79

Family	No. of Species	%	No. of Genera	%
Arecaceae	1	0.69	1	0.79
Asparagaceae	1	0.69	1	0.79
Capparidaceae	1	0.69	1	0.79
Combretaceae	1	0.69	1	0.79
Commelinaceae	1	0.69	1	0.79
Cyatheaceae	1	0.69	1	0.79
Dennstaedtiaceae	1	0.69	1	0.79
Ericaceae	1	0.69	1	0.79
Geraniaceae	1	0.69	1	0.79
Icacinaceae	1	0.69	1	0.79
Lobeliaceae	1	0.69	1	0.79
Melastomataceae	1	0.69	1	0.79
Melianthaceae	1	0.69	1	0.79
Musaceae	1	0.69	1	0.79
Myricaceae	1	0.69	1	0.79
Myrtaceae	1	0.69	1	0.79
Oliniaceae	1	0.69	1	0.79
Phytolaccaceae	1	0.69	1	0.79
Pittosporaceae	1	0.69	1	0.79
Plantaginaceae	1	0.69	1	0.79
Rhizophoraceae	1	0.69	1	0.79
Sapotaceae	1	0.69	1	0.79
Simarubaceae	1	0.69	1	0.79
Solanaceae	1	0.69	1	0.79
Sterculariaceae	1	0.69	1	0.79
Tiliaceae	1	0.69	1	0.79
Vitaceae	1	0.69	1	0.79
Zingeberaceae	1	0.69	1	0.79

Annex 4. Species indicator values for plant species at the Afromontane forest of TBB. Values in bold refer to species used for naming the plant communities.

Plant Name	Comm. 1	Comm. 2	Comm. 3	Comm. 4	Comm. 5	P. value
Apodytes dimidiata	**0.35**	0.13	0.12	0.03	0.03	0.005
Podocarpus falcatus	**0.34**	0.26	0.15	0.17	0.00	0.002
Syzygium guineense subsp. *afromontanum*	0.33	0.23	0.21	0.19	0.00	0.001
Olea capensis subsp. *macrocarpa*	0.26	0.19	0.22	0.18	0.08	0.003
Acanthus sennii	0.24	0.23	0.08	0.24	0.22	0.141
Maytenus undata	0.22	0.02	0.00	0.00	0.00	0.025
Embelia schimperi	0.10	0.00	0.00	0.02	0.00	0.142
Phoenix reclinata	0.09	0.00	0.00	0.00	0.00	0.135
Maesa lanceolata	0.08	0.00	0.00	0.01	0.07	0.319
Hypoestes triflora	0.06	0.05	0.03	0.04	0.01	0.894
Premna schimperi	0.06	0.02	0.00	0.00	0.00	0.330
Croton macrostachyus	0.01	**0.54**	0.06	0.05	0.00	0.001
Pouteria adolfi-friederici	0.04	**0.31**	0.09	0.25	0.00	0.016
Chionanthus mildbraedii	0.23	0.26	0.26	0.23	0.00	0.018
Allophylus abyssinicus	0.08	0.19	0.17	0.14	0.00	0.299
Setaria megaphylla	0.17	0.17	0.07	0.16	0.08	0.694
Calpurnia aurea	0.01	0.17	0.03	0.14	0.00	0.182
Landolphia buchananii	0.01	0.03	0.00	0.02	0.00	0.757
Solanecio mannii	0.00	0.03	0.00	0.00	0.00	1.000
Clutia abyssinica	0.00	0.03	0.00	0.00	0.00	1.000
Carissa spinarum	0.00	0.03	0.00	0.00	0.00	1.000
Rhus glutinosa	0.00	0.03	0.00	0.00	0.00	1.000
Macaranga capensis	0.03	0.17	**0.55**	0.00	0.00	0.001
Lepidotrichilia volkensii	0.00	0.00	**0.46**	0.24	0.00	0.001
Oxyanthus speciosus	0.07	0.03	0.43	0.33	0.00	0.001
Dracaena afromontana	0.05	0.03	0.41	0.39	0.00	0.001
Millettia ferruginea subsp. *darassana*	0.00	0.14	0.40	0.27	0.00	0.001
Maytenus gracilipes subsp. *arguta*	0.15	0.06	0.37	0.12	0.00	0.001
Desmodium repandum	0.01	0.01	0.35	0.01	0.01	0.009
Psychotria orophila	0.15	0.14	0.30	0.21	0.00	0.017
Cassipourea malosana	0.00	0.03	0.30	0.04	0.00	0.017
Elaeodendron buchananii	0.00	0.00	0.28	0.11	0.00	0.008
Olinia rochetiana	0.24	0.02	0.26	0.18	0.15	0.059
Ficus sur	0.06	0.17	0.24	0.13	0.00	0.122
Dombeya torrida	0.00	0.03	0.24	0.02	0.06	0.023
Sapium ellipticum	0.00	0.00	0.23	0.06	0.00	0.026

Plant Name	Comm. 1	Comm. 2	Comm. 3	Comm. 4	Comm. 5	P. value
Oplismenus hirtellus	0.18	0.20	0.21	0.18	0.11	0.654
Ritchiea albersii	0.00	0.00	0.16	0.09	0.00	0.044
Hippocratea goetzei	0.02	0.08	0.15	0.08	0.00	0.227
Dracaena steudneri	0.00	0.00	0.14	0.08	0.00	0.111
Rhamnus prinoides	0.01	0.02	0.03	0.02	0.00	1.000
Clausena anisata	0.01	0.02	0.08	**0.50**	0.00	0.001
Pittosporum viridiflorum	0.00	0.00	0.12	**0.46**	0.00	0.003
Rytigynia neglecta	0.02	0.08	0.38	0.40	0.00	0.001
Albizia gummifera	0.00	0.05	0.12	0.36	0.00	0.006
Teclea nobilis	0.05	0.10	0.30	0.35	0.00	0.002
Vepris dainellii	0.21	0.05	0.33	0.34	0.00	0.001
Schefflera abyssinica	0.00	0.00	0.28	0.31	0.00	0.005
Ehretia cymosa	0.00	0.02	0.03	0.31	0.00	0.009
Canthium oligocarpum	0.11	0.05	0.09	0.30	0.01	0.016
Prunus africana	0.07	0.09	0.07	0.29	0.00	0.021
Celtis africana	0.01	0.09	0.03	0.28	0.00	0.023
Brucea antidysenterica	0.00	0.00	0.20	0.26	0.00	0.025
Ekebergia capensis	0.00	0.00	0.08	0.22	0.00	0.025
Bersama abyssinica	0.16	0.21	0.06	0.21	0.03	0.259
Galiniera saxifraga	0.04	0.00	0.19	0.21	0.01	0.102
Oncoba spinosa	0.00	0.03	0.14	0.20	0.00	0.079
Polyscias fulva	0.14	0.12	0.10	0.16	0.00	0.493
Schefflera volkensii	0.00	0.00	0.05	0.13	0.06	0.161
Myrsine melanophloes	0.00	0.00	0.02	0.04	**0.66**	0.001
Hagenia abyssinica	0.01	0.00	0.00	0.00	**0.58**	0.001
Erica arborea	0.00	0.00	0.00	0.00	0.50	0.002
Maytenus addat	0.01	0.00	0.00	0.00	0.45	0.001
Arundinaria alpina	0.00	0.00	0.00	0.00	0.33	0.004
Ilex mitis	0.05	0.02	0.24	0.11	0.32	0.018
Acanthopale pubescens	0.12	0.07	0.02	0.18	0.30	0.018
Juniperus procera	0.04	0.00	0.00	0.00	0.26	0.006
Nuxia congesta	0.07	0.01	0.03	0.08	0.23	0.039
Hypericum revolutum	0.00	0.00	0.00	0.00	0.17	0.052
Myrica salicifolia	0.00	0.00	0.00	0.00	0.17	0.049
Osyris quadripartita	0.00	0.00	0.00	0.00	0.16	0.027
Myrsine africana	0.03	0.03	0.01	0.04	0.14	0.145

Annex 5. Species indicator values for plant species at the Afromontane forest of CCNP. Values in bold refer to the species used for naming the plant communities.

Plant Name	Comm. 1	Comm. 2	Comm. 3	P. value
Olea capensis subsp. *macrocarpa*	**0.70**	0.00	0.00	0.001
Macaranga capensis	**0.51**	0.04	0.08	0.001
Desmodium repandum	0.48	0.02	0.00	0.002
Apodytes dimidiata	0.45	0.00	0.16	0.002
Pouteria adolfi-friederici	0.40	0.02	0.01	0.001
Millettia ferruginea subsp. *darassana*	0.39	0.38	0.24	0.054
Vepris dainellii	0.38	0.23	0.28	0.131
Prunus africana	0.38	0.34	0.00	0.020
Oxyanthus speciosus	0.35	0.33	0.33	0.549
Psychotria orophila	0.33	0.32	0.27	0.776
Piper capense	0.32	0.10	0.00	0.026
Rothmannia urcelliformis	0.32	0.10	0.00	0.016
Bersama abyssinica	0.29	0.23	0.01	0.134
Albizia gummifera	0.26	0.09	0.04	0.154
Dombeya torrida	0.22	0.01	0.12	0.156
Teclea nobilis	0.21	0.10	0.19	0.699
Oncoba spinosa	0.18	0.08	0.04	0.375
Ehretia cymosa	0.18	0.07	0.02	0.218
Phoenix reclinata	0.18	0.07	0.02	0.278
Olea welwitschii	0.18	0.04	0.00	0.124
Cordia africana	0.18	0.04	0.00	0.127
Aframomum corrorima	0.13	0.00	0.00	0.134
Ritchiea albersii	0.12	0.00	0.02	0.271
Justicia schimperiana	0.04	0.02	0.02	1.000
Hypoestes triflora	0.03	0.00	0.00	1.000
Cyathea maniana	0.01	**0.84**	0.00	0.001
Lepidotrichilia volkensii	0.45	**0.49**	0.01	0.001
Polyscias fulva	0.31	0.47	0.01	0.003
Pittosporum viridiflorum	0.32	0.45	0.02	0.005
Hippocratea africana	0.12	0.43	0.00	0.002
Dracaena afromontana	0.36	0.42	0.16	0.001
Hippocratea goetzei	0.16	0.37	0.01	0.018
Galiniera saxifraga	0.29	0.36	0.05	0.055
Syzygium guineense subsp. *afromontanum*	0.30	0.35	0.35	0.252
Ficus sur	0.33	0.35	0.09	0.180
Schefflera abyssinica	0.13	0.34	0.04	0.024
Chionanthus mildbraedii	0.31	0.34	0.33	0.875
Canthium oligocarpum	0.19	0.30	0.20	0.408
Clausena anisata	0.16	0.30	0.14	0.253

Plant Name	**Comm. 1**	**Comm. 2**	**Comm. 3**	**P. value**
Myrsine melanophloes	0.00	0.27	0.00	0.002
Celtis africana	0.05	0.26	0.12	0.103
Brucea antidysenterica	0.14	0.25	0.03	0.126
Allophylus abyssinicus	0.20	0.24	0.17	0.796
Coffea arabica	0.00	0.00	**1.00**	0.001
Nuxia congesta	0.00	0.00	**1.00**	0.001
Agarista salicifolia	0.00	0.00	0.94	0.001
Acanthopale pubescens	0.08	0.06	0.80	0.001
Oplismenus hirtellus	0.11	0.09	0.67	0.001
Ilex mitis	0.12	0.04	0.65	0.001
Schefflera volkensii	0.00	0.00	0.63	0.001
Setaria megaphylla	0.04	0.07	0.54	0.002
Maesa lanceolata	0.01	0.00	0.50	0.001
Maytenus gracilipes subsp. *arguta*	0.28	0.24	0.43	0.008
Croton macrostachyus	0.07	0.29	0.38	0.037
Calpurnia aurea	0.00	0.00	0.38	0.001
Rytigynia neglecta	0.23	0.35	0.37	0.258
Achyranthes aspera	0.00	0.00	0.28	0.007
Landolphia buchananii	0.18	0.00	0.19	0.341
Dracaena steudneri	0.16	0.05	0.17	0.714
Cassipourea malosana	0.10	0.11	0.14	0.829
Ekebergia capensis	0.04	0.00	0.07	0.565
Vernonia amygdalina	0.00	0.00	0.06	0.525

Annex 6. Density of woody species along DBH-classes at the Afromontane forest of TBB

	DBH Classes											
Scientific Name	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total density**
Acanthus sennii	1.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Albizia gummifera	4.7	3.0	1.8	1.4	1.4	1.9	0.6	0.7	0.2	0.7	1.6	17.9
Allophylus abyssinicus	3.1	5.3	4.6	3.3	2.7	2.1	2.1	0.8	1.4	0.9	1.6	27.9
Apodytes dimidiata	6.2	5.7	5.1	3.0	1.4	1.5	1.7	1.0	1.7	2.0	1.9	31.3
Arundinaria alpina	36.5	11.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.2
Bersama abyssinica	25.6	13.5	4.3	1.6	0.3	0.0	0.0	0.0	0.1	0.2	0.0	45.6
Brucea antidysenterica	4.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1
Calpurnia aurea	12.8	8.2	3.7	0.4	0.2	0.0	0.1	0.0	0.0	0.0	0.0	25.3
Canthium oligocarpum	11.9	3.1	1.5	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	17.4
Carissa spinarum	0.6	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Cassipourea malosana	3.2	1.0	1.7	0.3	0.2	0.2	0.0	0.1	0.0	0.0	0.0	6.7
Celtis africana	3.3	1.2	2.3	1.0	0.8	1.2	0.7	0.7	0.8	0.1	1.2	13.2
Chionanthus mildbraedii	117.9	40.0	6.5	1.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	165.7
Clausena anisata	18.5	2.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.4
Clutia abyssinica	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Croton macrostachyus	0.4	0.6	2.7	2.4	3.6	5.4	3.4	4.4	2.1	1.1	2.9	28.9
Dombeya torrida	0.4	0.7	0.8	0.4	0.5	0.8	0.4	0.0	0.1	0.4	0.0	4.4
Dracaena afromontana	22.2	20.2	7.3	2.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	53.0
Dracaena steudneri	0.0	0.0	0.1	0.6	0.4	0.3	0.1	0.1	0.0	0.0	0.0	1.5
Ehretia cymosa	0.8	1.1	1.8	1.5	0.5	0.1	0.0	0.0	0.0	0.0	0.0	5.8
Ekebergia capensis	0.1	0.2	0.0	0.2	0.3	0.2	0.0	0.1	0.2	0.0	0.5	1.7
Elaeodendron buchananii	0.4	0.3	0.6	0.2	0.2	0.3	0.2	0.1	0.2	0.0	0.4	2.7

Scientific Name	DBH Classes											Total density
	1	2	3	4	5	6	7	8	9	10	11	
Erica arborea	30.2	9.0	2.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.3
Ficus sur	3.3	5.7	4.3	4.7	3.9	3.0	2.1	1.2	1.7	2.0	5.6	37.5
Galiniera saxifraga	3.6	3.6	3.5	0.8	0.3	0.1	0.0	0.0	0.0	0.0	0.0	11.8
Hagenia abyssinica	0.2	0.3	0.6	1.0	0.8	0.5	0.5	0.6	0.4	0.8	0.4	6.0
Hypericum revolutum	0.0	0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Ilex mitis	11.5	10.6	10.3	5.6	4.3	4.2	2.7	2.1	1.0	0.7	2.4	55.5
Juniperus procera	0.1	0.0	0.0	0.0	0.3	0.3	0.5	0.3	0.1	0.1	1.7	3.3
Justicia schimperiana	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Lepidotrichilia volkensii	3.8	3.3	3.5	1.3	0.3	0.2	0.0	0.1	0.0	0.0	0.0	12.4
Macaranga capensis	4.2	6.3	5.2	4.0	5.9	4.0	4.3	3.7	4.8	2.4	3.5	48.3
Maesa lanceolata	0.4	1.4	1.0	0.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	3.4
Maytenus addat	1.0	0.2	0.3	0.1	0.1	0.1	0.0	0.7	0.3	0.4	0.3	3.4
Maytenus gracilipes subsp. *arguta*	51.2	2.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53.8
Maytenus undata	3.0	1.0	1.1	0.9	0.7	0.7	0.0	0.3	0.4	0.1	0.2	8.4
Millettia ferruginea	13.9	15.7	13.3	6.2	4.4	2.4	1.3	0.8	0.5	0.0	0.1	58.8
Myrica salicifolia	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Myrsine africana	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
Myrsine melanophloes	16.5	12.8	3.1	1.5	1.5	0.8	1.6	0.9	0.4	0.2	0.0	39.3
Nuxia congesta	2.7	2.8	1.9	0.6	0.2	0.3	0.0	0.5	0.0	0.1	0.0	9.0
Olea capensis subsp. *macrocarpa*	42.5	53.5	33.7	12.4	7.3	8.8	5.6	4.7	3.0	2.9	14.0	188.5
Olinia rochetiana	6.1	7.7	8.4	7.0	7.0	2.5	4.7	3.3	1.9	1.7	4.5	54.8
Oncoba spinosa	2.5	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5
Osyris quadripartita	0.3	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
Oxyanthus speciosus	36.0	19.0	4.3	1.6	0.6	0.3	0.0	0.0	0.0	0.0	0.0	61.8

Scientific Name	DBH Classes 1	2	3	4	5	6	7	8	9	10	11	Total density
Phoenix reclinata	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Pittosporum viridiflorum	1.5	2.4	0.9	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	5.3
Podocarpus falcatus	39.4	22.7	13.2	6.6	5.6	5.5	1.8	2.3	3.2	1.5	3.7	105.3
Polyscias fulva	0.8	1.4	1.2	1.7	1.5	0.2	1.6	1.6	1.1	1.8	4.1	17.1
Pouteria adolfi–friederici	21.3	11.5	8.2	3.9	4.0	3.1	2.2	2.7	2.0	0.8	8.0	67.6
Premna schimperi	0.1	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Prunus africana	7.9	1.8	2.3	0.6	1.4	1.9	1.0	2.3	0.5	0.5	3.2	23.3
Psychotria orophila	66.2	24.7	4.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	96.0
Rhamnus prinoides	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Rhus glutinosa	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Ritchiea albersii	0.1	1.6	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4
Rytigynia neglecta	52.5	10.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	64.3
Sapium ellipticum	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.4	0.2	0.0	0.1	1.4
Schefflera abyssinica	0.0	0.2	0.0	0.1	0.2	0.4	0.2	0.0	0.1	0.2	3.8	5.1
Schefflera volkensii	0.3	0.0	0.1	0.3	0.1	0.3	0.1	0.0	0.2	0.3	1.6	3.2
Solanecio mannii	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Syzygium guineense subsp. *afromontanum*	32.2	33.0	22.2	11.1	6.1	6.8	7.6	5.0	3.7	4.6	17.5	149.8
Teclea nobilis	33.9	9.0	1.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.9
Vepris dainelli	31.5	23.2	13.9	4.8	1.8	0.5	0.3	0.1	0.0	0.0	0.0	76.0
Vernonia amygdalina	0.4	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Total	**802.9**	**420.6**	**213.4**	**98.9**	**72.4**	**60.9**	**47.7**	**41.3**	**32.0**	**26.8**	**84.7**	**1901.8**

Annex 7. Density of woody species along height-classes at the Afromontane forest of TBB

	Height Classes							
Scientific Name	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total density**
Acanthus sennii	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Albizia gummifera	5.4	3.8	2.9	2.2	1.8	1.0	0.8	17.9
Allophylus abyssinicus	7.0	9.1	7.3	3.7	0.8	0.0	0.0	27.9
Apodytes dimidiata	8.8	10.1	6.5	4.3	1.1	0.5	0.0	31.3
Arundinaria alpina	11.5	27.8	8.9	0.0	0.0	0.0	0.0	48.2
Bersama abyssinica	33.5	11.2	0.8	0.1	0.0	0.0	0.0	45.6
Brucea antidysenterica	4.7	0.4	0.0	0.0	0.0	0.0	0.0	5.1
Calpurnia aurea	13.2	11.1	1.0	0.0	0.0	0.0	0.0	25.3
Canthium oligocarpum	14.3	2.7	0.4	0.0	0.0	0.0	0.0	17.4
Carissa spinarum	0.4	0.6	0.0	0.0	0.0	0.0	0.0	0.9
Cassipourea malosana	4.3	1.6	0.8	0.0	0.0	0.0	0.0	6.7
Celtis africana	3.7	2.9	2.2	3.8	0.6	0.1	0.0	13.2
Chionanthus mildbraedii	145.3	19.6	0.8	0.0	0.0	0.0	0.0	165.7
Clausena anisata	18.8	2.5	0.0	0.0	0.0	0.0	0.0	21.4
Clutia abyssinica	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Croton macrostachyus	1.1	7.5	9.3	8.3	2.3	0.4	0.0	28.9
Dombeya torrida	0.8	2.2	1.4	0.0	0.0	0.0	0.0	4.4
Dracaena afromontana	52.4	0.6	0.0	0.0	0.0	0.0	0.0	53.0
Dracaena steudneri	0.0	1.0	0.4	0.1	0.0	0.0	0.0	1.5
Ehretia cymosa	2.7	2.0	1.1	0.0	0.0	0.0	0.0	5.8
Ekebergia capensis	0.2	0.4	0.3	0.4	0.4	0.1	0.0	1.7
Elaeodendron buchananii	0.3	0.8	0.9	0.4	0.3	0.0	0.0	2.7

Scientific Name	Height Classes							Total density
	1	2	3	4	5	6	7	
Erica arborea	41.0	0.4	0.0	0.0	0.0	0.0	0.0	41.3
Ficus sur	6.9	10.3	8.4	7.1	3.2	1.5	0.2	37.5
Galiniera saxifraga	10.4	1.4	0.0	0.0	0.0	0.0	0.0	11.8
Hagenia abyssinica	0.5	2.2	1.8	1.5	0.1	0.0	0.0	6.0
Hypericum revolutum	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.8
Ilex mitis	23.5	18.0	8.0	4.4	1.0	0.3	0.2	55.5
Juniperus procera	0.1	0.2	0.7	1.0	0.5	0.5	0.4	3.3
Justicia schimperiana	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Lepidotrichilia volkensii	6.8	5.6	0.1	0.0	0.0	0.0	0.0	12.4
Macaranga capensis	6.5	17.0	15.5	7.2	1.7	0.4	0.0	48.3
Maesa lanceolata	2.5	0.8	0.0	0.1	0.0	0.0	0.0	3.4
Maytenus addat	0.8	1.2	1.0	0.3	0.0	0.0	0.0	3.4
Maytenus gracilipes subsp. *arguta*	53.7	0.1	0.0	0.0	0.0	0.0	0.0	53.8
Maytenus undata	4.8	2.8	0.7	0.1	0.0	0.0	0.0	8.4
Millettia ferruginea subsp. *darassana*	19.1	24.3	11.9	2.9	0.6	0.0	0.0	58.8
Myrica salicifolia	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.4
Myrsine africana	6.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
Myrsine melanophloes	22.1	12.1	3.1	1.8	0.1	0.0	0.0	39.3
Nuxia congesta	4.7	4.3	0.0	0.0	0.0	0.0	0.0	9.0
Olea capensis subsp. *macrocarpa*	64.6	77.2	25.3	14.1	5.0	1.7	0.6	188.5
Olinia rochetiana	9.8	23.4	10.5	8.9	2.0	0.2	0.0	54.8
Oncoba spinosa	2.5	1.9	0.1	0.0	0.0	0.0	0.0	4.5
Osyris quadripartita	1.4	0.0	0.0	0.0	0.0	0.0	0.0	1.4
Oxyanthus speciosus	52.9	8.9	0.0	0.0	0.0	0.0	0.0	61.8

Scientific Name	Height Classes							Total density
	1	**2**	**3**	**4**	**5**	**6**	**7**	
Phoenix reclinata	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.5
Pittosporum viridiflorum	4.2	1.0	0.0	0.0	0.0	0.0	0.0	5.3
Podocarpus falcatus	47.5	32.7	12.1	8.6	3.3	1.0	0.2	105.3
Polyscias fulva	0.4	6.0	5.1	3.1	1.8	0.6	0.2	17.1
Pouteria adolfi–friederici	25.1	16.6	9.5	8.6	4.1	1.9	1.8	67.6
Premna schimperi	0.6	0.4	0.0	0.0	0.0	0.0	0.0	0.9
Prunus africana	9.3	4.7	3.3	3.7	2.1	0.2	0.0	23.3
Psychotria orophila	90.1	5.8	0.0	0.0	0.0	0.0	0.0	96.0
Rhamnus prinoides	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Rhus glutinosa	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Ritchiea albersii	2.0	0.4	0.0	0.0	0.0	0.0	0.0	2.4
Rytigynia neglecta	58.4	5.1	0.3	0.0	0.6	0.0	0.0	64.3
Sapium ellipticum	0.0	0.3	0.8	0.4	0.0	0.0	0.0	1.4
Schefflera abyssinica	0.2	0.5	2.4	0.7	1.2	0.1	0.0	5.1
Schefflera volkensii	0.5	1.0	1.0	0.2	0.5	0.0	0.0	3.2
Solanecio mannii	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Syzygium guineense subsp. *afromontanum*	50.9	44.8	25.4	17.5	8.0	2.8	0.3	149.8
Teclea nobilis	41.3	3.6	0.0	0.0	0.0	0.0	0.0	44.9
Vepris dainelli	51.8	23.1	1.1	0.0	0.0	0.0	0.0	76.0
Vernonia amygdalina	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.8
Total density	**1055.7**	**476.8**	**193.3**	**115.2**	**42.9**	**13.2**	**4.6**	**1901.8**

Annex 8. Density of woody species along DBH-classes at the Afromontane forest of CCNP

	DBH Classes											
Scientific Name	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total density**
Agarista salicifolia	0.9	2.0	2.4	0.9	3.3	1.1	1.8	0.7	0.9	0.5	0.5	15.1
Albizia gummifera	3.3	2.7	1.8	0.4	1.1	0.7	0.5	0.2	0.4	0.2	0.7	12.0
Allophylus abyssinicus	3.8	3.3	2.0	0.2	1.5	0.5	1.3	0.4	1.1	0.9	1.5	16.4
Apodytes dimidiata	3.1	3.3	4.4	2.2	1.1	0.4	1.8	1.5	2.4	2.2	5.8	28.1
Bersama abyssinica	8.7	3.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.8
Brucea antidysenterica	7.5	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5
Calpurnia aurea	2.6	0.7	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
Canthium oligocarpum	14.8	3.8	1.5	0.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	21.3
Cassipourea malosana	3.8	1.5	1.6	0.4	0.2	0.2	0.0	0.2	0.0	0.0	0.0	7.8
Celtis africana	4.0	1.8	2.7	0.7	0.7	1.5	0.7	1.1	0.7	0.2	1.5	15.7
Chionanthus mildbraedii	108.6	48.5	4.4	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	162.8
Clausena anisata	13.7	2.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.1
Coffea arabica	8.4	5.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.6
Cordia africana	1.5	0.5	0.2	0.7	0.0	0.2	0.0	0.4	0.0	0.2	0.0	3.6
Croton macrostachyus	0.4	0.4	1.5	0.9	2.0	2.6	3.1	2.2	0.9	0.7	2.6	17.1
Cyathea maniana	0.4	3.6	16.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.5
Dombeya torrida	0.5	1.3	1.5	0.7	0.7	1.3	0.5	0.0	0.2	0.5	0.0	7.3
Dracaena afromontana	26.8	51.7	37.5	10.7	6.4	0.4	0.0	0.0	0.0	0.0	0.0	133.5
Dracaena steudneri	0.0	0.0	0.4	2.2	1.5	1.1	0.4	0.4	0.0	0.0	0.0	5.8
Ehretia cymosa	0.5	1.1	1.3	2.7	0.4	0.2	0.0	0.0	0.0	0.0	0.0	6.2
Ekebergia capensis	0.2	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.5	1.1

Scientific Name	DBH Classes											Total density
	1	2	3	4	5	6	7	8	9	10	11	
Ficus sur	0.5	3.3	0.9	1.5	1.5	0.9	0.4	0.2	0.9	0.7	10.9	21.7
Galiniera saxifraga	17.9	8.6	32.2	6.9	0.0	0.4	0.0	0.0	0.0	0.0	0.0	65.9
Ilex mitis	4.7	5.8	7.5	2.9	1.1	2.0	0.9	1.1	2.6	1.8	12.8	43.2
Landolphia buchananii	0.9	0.5	1.3	0.4	0.4	0.5	0.4	0.2	0.4	0.0	0.7	5.6
Lepidotrichilia volkensii	18.0	14.0	13.7	4.7	1.3	0.7	0.0	0.4	0.5	0.5	2.2	56.1
Macaranga capensis	3.1	5.8	4.7	3.8	3.1	4.4	2.9	2.6	4.4	1.3	2.2	38.3
Maesa lanceolata	0.4	1.5	2.9	0.5	0.0	0.4	0.0	0.0	0.0	0.0	0.0	5.6
Maytenus gracilipes subsp. *arguta*	66.3	3.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.7
Millettia ferruginea	11.7	12.8	11.7	6.9	5.8	2.6	1.5	0.7	0.0	0.0	0.2	53.7
Myrsine melanophloes	1.8	1.6	0.2	0.0	0.0	0.0	0.5	0.2	0.0	0.0	0.0	4.4
Nuxia congesta	5.8	9.7	4.9	1.5	0.0	0.7	0.0	1.6	0.0	0.0	0.0	24.2
Olea capensis subsp. *macrocarpa*	1.1	2.2	0.2	0.0	0.0	0.2	0.4	0.0	0.7	1.5	7.5	13.7
Olea welwitschii	1.5	0.5	0.2	0.7	0.0	0.2	0.0	0.4	0.0	0.2	0.0	3.6
Oncoba spinosa	3.6	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2
Oxyanthus speciosus	90.3	52.5	11.5	3.8	1.3	0.5	0.0	0.0	0.0	0.0	0.0	159.9
Phoenix reclinata	0.5	1.1	1.3	2.7	0.4	0.2	0.0	0.0	0.0	0.0	0.0	6.2
Pittosporum viridiflorum	12.9	6.4	2.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.9
Polyscias fulva	1.3	2.2	2.0	2.4	0.4	0.4	1.3	0.7	1.3	1.3	4.4	17.5
Pouteria adolfi–friederici	1.1	0.5	0.4	0.0	0.2	0.4	0.0	0.2	0.0	0.5	4.9	8.2
Prunus africana	14.6	2.9	1.6	0.4	2.7	1.1	1.3	2.0	2.0	1.8	14.9	45.4
Psychotria orophila	63.4	38.4	7.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	109.5
Ritchiea albersii	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Rothmannia urcelliformis	1.3	4.2	2.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0
Rytigynia neglecta	40.8	8.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	50.6

	DBH Classes											
Scientific Name	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total density**
Schefflera abyssinica	0.0	0.5	0.0	0.0	0.5	0.4	0.5	0.4	0.2	0.4	7.7	10.6
Schefflera volkensii	0.5	0.2	0.2	0.2	0.2	0.5	0.4	0.0	0.2	0.9	3.5	6.7
Syzygium guineense subsp. *afromontanum*	20.6	24.8	22.0	11.1	5.5	6.6	6.2	4.0	3.6	5.8	12.2	122.4
Teclea nobilis	6.4	2.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.2
Vepris dainellii	15.3	12.0	6.4	2.4	0.4	0.2	0.2	0.0	0.0	0.0	0.0	36.8
Vernonia amygdalina	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Total	**620.0**	**371.6**	**221.1**	**80.5**	**43.9**	**33.3**	**27.0**	**21.5**	**23.3**	**22.6**	**97.1**	**1561.9**

Annex 9. Density of woody species along height-classes at the Afromontane forest of CCNP

Scientific Name	Height Classes 1	2	3	4	5	6	7	Total density
Agarista salicifolia	2.7	6.9	5.5	0.0	0.0	0.0	0.0	15.1
Albizia gummifera	4.0	2.4	1.6	1.6	1.1	0.7	0.5	12.0
Allophylus abyssinicus	5.8	3.1	4.9	2.2	0.4	0.0	0.0	16.4
Apodytes dimidiata	6.4	5.8	4.2	4.9	3.1	1.1	2.6	28.1
Bersama abyssinica	10.6	2.0	0.2	0.0	0.0	0.0	0.0	12.8
Brucea antidysenterica	8.9	0.5	0.0	0.0	0.0	0.0	0.0	9.5
Calpurnia aurea	1.6	2.2	0.4	0.0	0.0	0.0	0.0	4.2
Canthium oligocarpum	17.7	3.3	0.4	0.0	0.0	0.0	0.0	21.3
Cassipourea malosana	5.3	1.6	0.9	0.0	0.0	0.0	0.0	7.8
Celtis africana	4.7	3.6	2.4	4.2	0.5	0.2	0.0	15.7
Chionanthus mildbraedii	140.3	21.9	0.7	0.0	0.0	0.0	0.0	162.8
Clausena anisata	14.9	2.2	0.0	0.0	0.0	0.0	0.0	17.1
Coffea arabica	14.6	0.0	0.0	0.0	0.0	0.0	0.0	14.6
Cordia africana	1.5	0.9	0.5	0.5	0.0	0.2	0.0	3.6
Croton macrostachyus	0.4	3.6	6.9	5.3	0.9	0.0	0.0	17.1
Cyathea maniana	13.1	7.8	0.5	0.0	0.0	0.0	0.0	21.5
Dombeya torrida	1.5	3.6	2.2	0.0	0.0	0.0	0.0	7.3
Dracaena afromontana	133.3	0.2	0.0	0.0	0.0	0.0	0.0	133.5
Dracaena steudneri	0.0	4.0	1.5	0.4	0.0	0.0	0.0	5.8
Ehretia cymosa	3.1	2.2	0.9	0.0	0.0	0.0	0.0	6.2
Ekebergia capensis	0.4	0.2	0.0	0.2	0.2	0.2	0.0	1.1
Ficus sur	2.6	5.8	6.4	3.8	1.6	0.4	1.1	21.7

Scientific Name	Height Classes							Total density
	1	2	3	4	5	6	7	
Galiniera saxifraga	65.9	0.0	0.0	0.0	0.0	0.0	0.0	65.9
Ilex mitis	12.6	14.9	6.7	7.3	0.9	0.5	0.2	43.2
Landolphia buchananii	0.7	1.6	2.0	0.7	0.5	0.0	0.0	5.6
Lepidotrichilia volkensii	31.0	21.3	0.7	1.1	0.5	0.4	1.1	56.1
Macaranga capensis	4.6	12.4	14.9	4.2	2.0	0.2	0.0	38.3
Maesa lanceolata	4.6	1.1	0.0	0.0	0.0	0.0	0.0	5.6
Maytenus gracilipes subsp. *arguta*	70.5	0.2	0.0	0.0	0.0	0.0	0.0	70.7
Millettia ferruginea	14.9	23.1	14.6	0.5	0.5	0.0	0.0	53.7
Myrsine melanophloes	2.4	1.6	0.2	0.2	0.0	0.0	0.0	4.4
Nuxia congesta	10.7	13.5	0.0	0.0	0.0	0.0	0.0	24.2
Olea capensis subsp. *macrocarpa*	1.1	5.3	4.9	1.5	0.0	0.9	0.0	13.7
Olea welwitschii	1.5	0.9	0.5	0.5	0.0	0.2	0.0	3.6
Oncoba spinosa	3.6	2.6	0.0	0.0	0.0	0.0	0.0	6.2
Oxyanthus speciosus	142.4	17.5	0.0	0.0	0.0	0.0	0.0	159.9
Phoenix reclinata	3.1	2.2	0.9	0.0	0.0	0.0	0.0	6.2
Pittosporum viridiflorum	20.2	1.6	0.0	0.0	0.0	0.0	0.0	21.9
Polyscias fulva	0.7	6.9	6.0	1.6	1.6	0.4	0.2	17.5
Pouteria adolfi–friederici	1.6	1.5	1.1	0.7	1.5	1.1	0.7	8.2
Prunus africana	17.1	10.2	6.0	6.9	3.6	0.7	0.7	45.4
Psychotria orophila	103.5	6.0	0.0	0.0	0.0	0.0	0.0	109.5
Ritchiea albersii	1.3	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Rothmannia urcelliformis	5.8	2.2	0.0	0.0	0.0	0.0	0.0	8.0
Rytigynia neglecta	43.5	6.2	0.5	0.0	0.4	0.0	0.0	50.6
Schefflera abyssinica	0.5	0.9	5.1	1.1	2.7	0.2	0.0	10.6

Scientific Name	Height Classes 1	2	3	4	5	6	7	Total density
Schefflera volkensii	1.1	1.6	2.4	0.5	1.1	0.0	0.0	6.7
Syzygium guineense subsp. *afromontanum*	35.9	39.2	22.6	16.0	6.2	2.2	0.4	122.4
Teclea nobilis	9.1	1.1	0.0	0.0	0.0	0.0	0.0	10.2
Vepris dainellii	24.0	12.6	0.2	0.0	0.0	0.0	0.0	36.8
Vernonia amygdalina	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Total density	**1027.7**	**292.2**	**129.5**	**66.1**	**29.5**	**9.5**	**7.5**	**1561.9**

Annex 10. Frequency, Density, Basal Area and Important value indices of Woody species at the Afromontane forest of TBB

Where: P=Number of plot where a species was present, F=Frequency, N=Number/count of individuals, D=Density, BA=Basal Area, Av.BA=Average BA, DO=Dominance, RF=Relative Frequency, RD=Relative Density, RDO=Relative dominance and IVI=Importance value index.

Scientific Name	P	F	N	D	BA	Av. BA	DO	RF	RD	RDO	IVI
Acanthus sennii	7	0.0593	20	1.8832	0.0022	0.0001	0.0022	0.2828	0.0990	0.0030	0.3849
Albizia gummifera	38	0.3220	190	17.8908	1.1529	0.0061	1.1529	1.5354	0.9407	1.5796	4.0557
Allophylus abyssinicus	66	0.5593	296	27.8719	1.8143	0.0061	1.8143	2.6667	1.4656	2.4859	6.6181
Apodytes dimidiata	71	0.6017	332	31.2618	1.8181	0.0055	1.8181	2.8687	1.6438	2.4911	7.0036
Arundinaria alpina	2	0.0169	512	48.2109	0.0946	0.0002	0.0946	0.0808	2.5350	0.1297	2.7455
Bersama abyssinica	80	0.6780	484	45.5744	0.2395	0.0005	0.2395	3.2323	2.3964	0.3281	5.9569
Brucea antidysenterica	28	0.2373	54	5.0847	0.0094	0.0002	0.0094	1.1313	0.2674	0.0129	1.4115
Calpurnia aurea	34	0.2881	269	25.3296	0.1214	0.0005	0.1214	1.3737	1.3319	0.1664	2.8720
Canthium oligocarpum	56	0.4746	185	17.4200	0.0690	0.0004	0.0690	2.2626	0.9160	0.0946	3.2732
Carissa spinarum	1	0.0085	10	0.9416	0.0037	0.0004	0.0037	0.0404	0.0495	0.0050	0.0949
Cassipourea malosana	26	0.2203	71	6.6855	0.0652	0.0009	0.0652	1.0505	0.3515	0.0894	1.4914
Celtis africana	35	0.2966	140	13.1827	0.7750	0.0055	0.7750	1.4141	0.6932	1.0619	3.1692
Chionanthus mildbraedii	111	0.9407	1760	165.7250	0.4437	0.0003	0.4437	4.4848	8.7142	0.6080	13.8070
Clausena anisata	41	0.3475	227	21.3748	0.0377	0.0002	0.0377	1.6566	1.1239	0.0517	2.8321
Clutia abyssinica	1	0.0085	4	0.3766	0.0002	0.0000	0.0002	0.0404	0.0198	0.0003	0.0605
Croton macrostachyus	60	0.5085	307	28.9077	2.6504	0.0086	2.6504	2.4242	1.5200	3.6314	7.5757
Dombeya torrida	19	0.1610	47	4.4256	0.1990	0.0042	0.1990	0.7677	0.2327	0.2727	1.2731
Dracaena afromontana	73	0.6186	563	53.0132	0.3028	0.0005	0.3028	2.9495	2.7875	0.4149	6.1519
Dracaena steudneri	11	0.0932	16	1.5066	0.0615	0.0038	0.0615	0.4444	0.0792	0.0843	0.6080
Ehretia cymosa	23	0.1949	62	5.8380	0.0863	0.0014	0.0863	0.9293	0.3070	0.1183	1.3545

Scientific Name	P	F	N	D	BA	Av. BA	DO	RF	RD	RDO	IVI
Ekebergia capensis	15	0.1271	18	1.6949	0.2750	0.0153	0.2750	0.6061	0.0891	0.3768	1.0720
Elaeodendron buchananii	18	0.1525	29	2.7307	0.2517	0.0087	0.2517	0.7273	0.1436	0.3448	1.2157
Erica arborea	3	0.0254	439	41.3371	0.1071	0.0002	0.1071	0.1212	2.1736	0.1468	2.4416
Ficus sur	65	0.5508	398	37.4765	3.5005	0.0088	3.5005	2.6263	1.9706	4.7962	9.3931
Galiniera saxifraga	35	0.2966	125	11.7702	0.1027	0.0008	0.1027	1.4141	0.6189	0.1407	2.1737
Hagenia abyssinica	6	0.0508	64	6.0264	0.5173	0.0081	0.5173	0.2424	0.3169	0.7088	1.2681
Hypericum revolutum	1	0.0085	8	0.7533	0.0096	0.0012	0.0096	0.0404	0.0396	0.0131	0.0931
Ilex mitis	65	0.5508	589	55.4614	2.3266	0.0040	2.3266	2.6263	2.9163	3.1878	8.7303
Juniperus procera	6	0.0508	35	3.2957	1.1177	0.0319	1.1177	0.2424	0.1733	1.5315	1.9472
Justicia schimperiana	2	0.0169	3	0.2825	0.0004	0.0001	0.0004	0.0808	0.0149	0.0005	0.0962
Lepidotrichilia volkensii	35	0.2966	132	12.4294	0.1186	0.0009	0.1186	1.4141	0.6536	0.1625	2.2302
Macaranga capensis	54	0.4576	513	48.3051	3.6700	0.0072	3.6700	2.1818	2.5400	5.0285	9.7503
Maesa lanceolata	10	0.0847	36	3.3898	0.0373	0.0010	0.0373	0.4040	0.1782	0.0512	0.6334
Maytenus addat	6	0.0508	36	3.3898	0.2814	0.0078	0.2814	0.2424	0.1782	0.3855	0.8062
Maytenus gracilipes subsp. *arguta*	72	0.6102	571	53.7665	0.0624	0.0001	0.0624	2.9091	2.8272	0.0856	5.8218
Maytenus undata	8	0.0678	89	8.3804	0.2576	0.0029	0.2576	0.3232	0.4407	0.3530	1.1169
Millettia ferruginea subsp. *darassana*	75	0.6356	624	58.7571	1.0101	0.0016	1.0101	3.0303	3.0896	1.3840	7.5039
Myrica salicifolia	1	0.0085	4	0.3766	0.0018	0.0005	0.0018	0.0404	0.0198	0.0025	0.0627
Myrsine africana	13	0.1102	64	6.0264	0.0052	0.0001	0.0052	0.5253	0.3169	0.0071	0.8493
Myrsine melanophloes	25	0.2119	417	39.2655	0.5792	0.0014	0.5792	1.0101	2.0647	0.7936	3.8683
Nuxia congesta	33	0.2797	96	9.0395	0.1419	0.0015	0.1419	1.3333	0.4753	0.1944	2.0030
Olea capensis subsp. *macrocarpa*	112	0.9492	2002	188.5122	10.3587	0.0052	10.3587	4.5253	9.9124	14.1931	28.6307
Olinia rochetiana	83	0.7034	582	54.8023	3.5978	0.0062	3.5978	3.3535	2.8816	4.9295	11.1647

Scientific Name	**P**	**F**	**N**	**D**	**BA**	**Av. BA**	**DO**	**RF**	**RD**	**RDO**	**IVI**
Oncoba spinosa	27	0.2288	48	4.5198	0.0145	0.0003	0.0145	1.0909	0.2377	0.0199	1.3484
Osyris quadripartita	2	0.0169	15	1.4124	0.0051	0.0003	0.0051	0.0808	0.0743	0.0069	0.1620
Oxyanthus speciosus	72	0.6102	656	61.7702	0.2665	0.0004	0.2665	2.9091	3.2480	0.3651	6.5222
Phoenix reclinata	2	0.0169	5	0.4708	0.0106	0.0021	0.0106	0.0808	0.0248	0.0145	0.1200
Pittosporum viridiflorum	27	0.2288	56	5.2731	0.0388	0.0007	0.0388	1.0909	0.2773	0.0532	1.4214
Podocarpus falcatus	103	0.8729	1118	105.2731	3.1887	0.0029	3.1887	4.1616	5.5355	4.3690	14.0661
Polyscias fulva	57	0.4831	182	17.1375	2.4413	0.0134	2.4413	2.3030	0.9011	3.3449	6.5491
Pouteria adolfi-friederici	74	0.6271	718	67.6083	7.2932	0.0102	7.2932	2.9899	3.5550	9.9928	16.5377
Premna schimperi	4	0.0339	10	0.9416	0.0070	0.0007	0.0070	0.1616	0.0495	0.0096	0.2207
Prunus africana	54	0.4576	247	23.2580	2.2771	0.0092	2.2771	2.1818	1.2230	3.1200	6.5247
Psychotria orophila	86	0.7288	1019	95.9510	0.2655	0.0003	0.2655	3.4747	5.0453	0.3638	8.8838
Rhamnus prinoides	1	0.0085	2	0.1883	0.0001	0.0001	0.0001	0.0404	0.0099	0.0002	0.0505
Rhus glutinosa	1	0.0085	2	0.1883	0.0004	0.0002	0.0004	0.0404	0.0099	0.0006	0.0509
Ritchiea albersii	14	0.1186	25	2.3540	0.0160	0.0006	0.0160	0.5657	0.1238	0.0219	0.7114
Rytigynia neglecta	78	0.6610	683	64.3126	0.2147	0.0003	0.2147	3.1515	3.3817	0.2942	6.8274
Sapium ellipticum	14	0.1186	15	1.4124	0.1593	0.0106	0.1593	0.5657	0.0743	0.2183	0.8582
Schefflera abyssinica	33	0.2797	54	5.0847	4.2480	0.0787	4.2480	1.3333	0.2674	5.8204	7.4211
Schefflera volkensii	14	0.1186	34	3.2015	1.7161	0.0505	1.7161	0.5657	0.1683	2.3513	3.0853
Solanecio mannii	1	0.0085	1	0.0942	0.0012	0.0012	0.0012	0.0404	0.0050	0.0016	0.0470
Syzygium guineense subsp. *afromontanum*	106	0.8983	1591	149.8117	11.8748	0.0075	11.8748	4.2828	7.8774	16.2703	28.4305
Teclea nobilis	79	0.6695	477	44.9153	0.1072	0.0002	0.1072	3.1919	2.3617	0.1469	5.7005
Vepris dainelli	93	0.7881	807	75.9887	0.5533	0.0007	0.5533	3.7576	3.9956	0.7580	8.5113
Vernonia amygdalina	7	0.0593	9	0.8475	0.0076	0.0008	0.0076	0.2828	0.0446	0.0104	0.3378

Annex 11. Frequency, Density, Basal area and Important value indices of Woody species at the Afromontane forest of CCNP

Where: P=Number of plot where a species was present, F=Frequency, N=Number/count of individuals, D=Density, BA=Basal Area, Av.BA=Average BA, DO=Dominance, RF=Relative Frequency, RD=Relative Density, RDO=Relative dominance and IVI=Importance value index.

Scientific Name	**P**	**F**	**N**	**D**	**BA**	**Av. BA**	**DO**	**RF**	**RD**	**RDO**	**IVI**
Albizia gummifera	24	0.3934	66	12.0219	0.8722	0.0132	0.8722	1.5335	0.7697	1.1817	3.4849
Allophylus abyssinicus	38	0.6230	90	16.3934	1.4615	0.0162	1.4615	2.4281	1.0496	1.9802	5.4578
Agarista salicifolia	18	0.2951	83	15.1184	0.8406	0.0101	0.8406	1.1502	0.9679	1.1388	3.2569
Apodytes dimidiata	28	0.4590	154	28.0510	3.2368	0.0210	3.2368	1.7891	1.7959	4.3854	7.9705
Bersama abyssinica	28	0.4590	70	12.7505	0.0327	0.0005	0.0327	1.7891	0.8163	0.0444	2.6498
Brucea antidysenterica	23	0.3770	52	9.4718	0.0180	0.0003	0.0180	1.4696	0.6064	0.0244	2.1005
Calpurnia aurea	6	0.0984	23	4.1894	0.0207	0.0009	0.0207	0.3834	0.2682	0.0280	0.6797
Canthium oligocarpum	40	0.6557	117	21.3115	0.0863	0.0007	0.0863	2.5559	1.3644	0.1170	4.0373
Cassipourea malosana	20	0.3279	43	7.8324	0.0794	0.0018	0.0794	1.2780	0.5015	0.1076	1.8870
Celtis africana	21	0.3443	86	15.6648	0.9234	0.0107	0.9234	1.3419	1.0029	1.2511	3.5959
Chionanthus mildbraedii	60	0.9836	894	162.8415	0.4560	0.0005	0.4560	3.8339	10.4257	0.6178	14.8773
Clausena anisata	35	0.5738	94	17.1220	0.0362	0.0004	0.0362	2.2364	1.0962	0.0491	3.3817
Coffea arabica	16	0.2623	80	14.5719	0.0425	0.0005	0.0425	1.0224	0.9329	0.0576	2.0129
Cordia africana	10	0.1639	20	3.6430	0.1040	0.0052	0.1040	0.6390	0.2332	0.1409	1.0131
Croton macrostachyus	38	0.6230	94	17.1220	1.9406	0.0206	1.9406	2.4281	1.0962	2.6293	6.1536
Cyathea maniana	17	0.2787	118	21.4936	0.2401	0.0020	0.2401	1.0863	1.3761	0.3253	2.7877
Dombeya torrida	18	0.2951	40	7.2860	0.3083	0.0077	0.3083	1.1502	0.4665	0.4177	2.0343
Dracaena afromontana	61	1.0000	733	133.5155	1.2802	0.0017	1.2802	3.8978	8.5481	1.7345	14.1804
Dracaena steudneri	23	0.3770	32	5.8288	0.2381	0.0074	0.2381	1.4696	0.3732	0.3226	2.1654

Scientific Name	P	F	N	D	BA	Av. BA	DO	RF	RD	RDO	IVI
Ehretia cymosa	15	0.2459	34	6.1931	0.1084	0.0032	0.1084	0.9585	0.3965	0.1468	1.5018
Ekebergia capensis	5	0.0820	6	1.0929	0.3125	0.0521	0.3125	0.3195	0.0700	0.4234	0.8129
Ficus sur	45	0.7377	119	21.6758	6.2457	0.0525	6.2457	2.8754	1.3878	8.4622	12.7253
Galiniera saxifraga	39	0.6393	362	65.9381	0.6160	0.0017	0.6160	2.4920	4.2216	0.8346	7.5482
Ilex mitis	61	1.0000	237	43.1694	5.7740	0.0244	5.7740	3.8978	2.7638	7.8231	14.4847
Landolphia buchananii	20	0.3279	31	5.6466	0.4900	0.0158	0.4900	1.2780	0.3615	0.6639	2.3033
Lepidotrichilia volkensii	46	0.7541	308	56.1020	1.2635	0.0041	1.2635	2.9393	3.5918	1.7118	8.2430
Macaranga capensis	34	0.5574	210	38.2514	2.6910	0.0128	2.6910	2.1725	2.4490	3.6460	8.2675
Maesa lanceolata	11	0.1803	31	5.6466	0.0713	0.0023	0.0713	0.7029	0.3615	0.0967	1.1611
Maytenus gracilipes subsp. *arguta*	58	0.9508	388	70.6740	0.0876	0.0002	0.0876	3.7061	4.5248	0.1186	8.3495
Millettia ferruginea subsp. *darassana*	61	1.0000	295	53.7341	1.0243	0.0035	1.0243	3.8978	3.4402	1.3877	8.7257
Myrsine melanophloes	4	0.0656	24	4.3716	0.0773	0.0032	0.0773	0.2556	0.2799	0.1047	0.6402
Nuxia congesta	16	0.2623	133	24.2259	0.3605	0.0027	0.3605	1.0224	1.5510	0.4885	3.0618
Olea capensis subsp. *macrocarpa*	25	0.4098	75	13.6612	3.5379	0.0472	3.5379	1.5974	0.8746	4.7934	7.2655
Olea welwitschii	10	0.1639	20	3.6430	0.1040	0.0052	0.1040	0.6390	0.2332	0.1409	1.0131
Oncoba spinosa	18	0.2951	34	6.1931	0.0197	0.0006	0.0197	1.1502	0.3965	0.0267	1.5734
Oxyanthus speciosus	61	1.0000	878	159.9271	0.6755	0.0008	0.6755	3.8978	10.2391	0.9152	15.0521
Phoenix reclinata	15	0.2459	34	6.1931	0.1084	0.0032	0.1084	0.9585	0.3965	0.1468	1.5018
Pittosporum viridiflorum	41	0.6721	120	21.8579	0.0838	0.0007	0.0838	2.6198	1.3994	0.1136	4.1328
Polyscias fulva	39	0.6393	96	17.4863	2.1427	0.0223	2.1427	2.4920	1.1195	2.9031	6.5146
Pouteria adolfi–friederici	61	1.0000	45	8.1967	4.6607	0.1036	4.6607	3.8978	0.5248	6.3147	10.7372

Scientific Name	P	F	N	D	BA	Av. BA	DO	RF	RD	RDO	IVI
Prunus africana	33	0.5410	249	45.3552	7.9936	0.0321	7.9936	2.1086	2.9038	10.8304	15.8428
Psychotria orophila	56	0.9180	601	109.4718	0.3705	0.0006	0.3705	3.5783	7.0087	0.5020	11.0891
Ritchiea albersii	6	0.0984	7	1.2750	0.0057	0.0008	0.0057	0.3834	0.0816	0.0077	0.4727
Rothmannia urcelliformis	19	0.3115	44	8.0146	0.0612	0.0014	0.0612	1.2141	0.5131	0.0829	1.8100
Rytigynia neglecta	57	0.9344	278	50.6375	0.1627	0.0006	0.1627	3.6422	3.2420	0.2204	7.1045
Schefflera abyssinica	27	0.4426	58	10.5647	8.7906	0.1516	8.7906	1.7252	0.6764	11.9102	14.3118
Schefflera volkensii	10	0.1639	37	6.7395	4.1978	0.1135	4.1978	0.6390	0.4315	5.6875	6.7580
Syzygium guineense subsp. *afromontanum*	61	1.0000	672	122.4044	9.2791	0.0138	9.2791	3.8978	7.8367	12.5721	24.3066
Teclea nobilis	31	0.5082	56	10.2004	0.0324	0.0006	0.0324	1.9808	0.6531	0.0439	2.6778
Vepris dainellii	55	0.9016	202	36.7942	0.2408	0.0012	0.2408	3.5144	2.3557	0.3262	6.1963
Vernonia amygdalina	1	0.0164	2	0.3643	0.0004	0.0002	0.0004	0.0639	0.0233	0.0006	0.0878

Annex 12. Seedling and Saplings at the Afromontane forest of TBB

Plant Name	Seedling Count	Sapling Count	Seedling Density (stem ha-^{1})	Sapling Density (stem ha-^{1})
Acanthus sennii	13	187	1.22	17.61
Albizia gummifera	153	143	14.41	13.47
Allophylus abyssinicus	40	47	3.77	4.43
Apodytes dimidiata	20	65	1.88	6.12
Arundinaria alpina	5	111	0.47	10.45
Bersama abyssinica	401	554	37.76	52.17
Brucea antidysenterica	11	44	1.04	4.14
Calpurnia aurea	118	179	11.11	16.85
Canthium oligocarpum	17	75	1.60	7.06
Carissa spinarum	0	1	0.00	0.09
Cassipourea malosana	8	30	0.75	2.82
Celtis africana	15	82	1.41	7.72
Chionanthus mildbraedii	252	356	23.73	33.52
Clausena anisata	75	504	7.06	47.46
Clutia abyssinica	2	12	0.19	1.13
Croton macrostachyus	3	14	0.28	1.32
Dombeya torrida	12	14	1.13	1.32
Dracaena afromontana	137	448	12.90	42.18
Dracaena steudneri	291	95	27.40	8.95
Ehretia cymosa	0	1	0.00	0.09
Embelia schimperi	64	111	6.03	10.45
Erica arborea	10	16	0.94	1.51
Erythrococca trichogyne	283	107	26.65	10.08
Ficus sur	6	23	0.56	2.17
Flacortia indica	2	5	0.19	0.47
Galiniera saxifraga	206	198	19.40	18.64
Hagenia abyssinica	3	5	0.28	0.47
Ilex mitis	11	98	1.04	9.23
Juniperus procera	17	11	1.60	1.04
Justicia schimperiana	39	56	3.67	5.27
Landolphia buchananii	78	142	7.34	13.37
Lepidotrichilia volkensii	54	64	5.08	6.03
Macaranga capensis	18	48	1.69	4.52
Maesa lanceolata	15	23	1.41	2.17
Maytenus gracilipes subsp. *arguta*	1941	4240	182.77	399.25
Maytenus undata	4	20	0.38	1.88
Millettia ferruginea subsp. *darassana*	49	79	4.61	7.44
Myrsine africana	426	1600	40.11	150.66

Plant Name	Seedling Count	Sapling Count	Seedling Density (stem ha-[1])	Sapling Density (stem ha-[1])
Myrsine melanophloes	66	320	6.21	30.13
Nuxia congesta	3	24	0.28	2.26
Olea capensis subsp. *macrocarpa*	321	841	30.23	79.19
Olinia rochetiana	0	38	0.00	3.58
Osyris quadripartita	1	4	0.09	0.38
Oxyanthus speciosus	296	551	27.87	51.88
Phoenix reclinata	2	9	0.19	0.85
Pittosporum viridiflorum	13	35	1.22	3.30
Podocarpus falcatus	111	482	10.45	45.39
Polyscias fulva	15	44	1.41	4.14
Pouteria adolfi-friederici	118	212	11.11	19.96
Prmnia schimperi	0	2	0.00	0.19
Prunus africana	36	125	3.39	11.77
Psychotria orophila	559	1441	52.64	135.69
Rhamnus prinoides	5	18	0.47	1.69
Rytigynia neglecta	278	1284	26.18	120.90
Syzygium guineense subsp. *afromontanum*	597	315	56.21	29.66
Teclea nobilis	125	251	11.77	23.63
Trichilia dregeana	27	109	2.54	10.26
Vepris dainellii	437	637	41.15	59.98

Annex 13. Density of Seedlings and Saplings of the Afromontane forest of CCNP

Plant Name	Seedling Count	Sapling Count	Seedling Density (stem ha-1)	Sapling Density (stem ha-1)
Albizia gummifera	127	77	23.13	14.03
Allophylus abyssinicus	38	17	6.92	3.10
Apodytes dimidiata	19	22	3.46	4.01
Bersama abyssinica	3	19	0.55	3.46
Brucea antidysenterica	3	10	0.55	1.82
Canthium oligocarpum	27	42	4.92	7.65
Cassipourea malosana	53	45	9.65	8.20
Chionanthus mildbraedii	637	480	116.03	87.43
Clausena anisata	94	263	17.12	47.91
Coffea arabica	363	167	66.12	30.42
Croton macrostachyus	19	43	3.46	7.83
Cyathea manniana	109	75	19.85	13.66
Dombeya torrida	1	6	0.18	1.09
Dracaena afromontana	122	109	22.22	19.85
Dracaena steudneri	306	98	55.74	17.85
Erythrococca trichogyne	361	166	65.76	30.24
Ficus sur	2	4	0.36	0.73
Galiniera saxifraga	461	292	83.97	53.19
Ilex mitis	98	70	17.85	12.75
Justicia schimperiana	116	39	21.13	7.10
Landolphia buchananii	17	16	3.10	2.91
Lepidotrichilia volkensii	371	273	67.58	49.73
Macaranga capensis	10	10	1.82	1.82
Maesa lanceolata	28	23	5.10	4.19
Maytenus gracilipes subsp. *arguta*	161	121	29.33	22.04
Millettia ferruginea subsp. *darassana*	43	34	7.83	6.19
Olea capensis subsp. *macrocarpa*	13	53	2.37	9.65
Olea welwitschii	14	11	2.55	2.00
Oxyanthus speciosus	458	369	83.42	67.21
Phoenix reclinata	31	34	5.65	6.19
Pittosporum viridiflorum	82	88	14.94	16.03
Polyscias fulva	41	25	7.47	4.55
Pouteria adolfi-friederici	222	42	40.44	7.65
prunus africana	123	106	22.40	19.31
Psychotria orophila	246	374	44.81	68.12
Rothmannia urcelliformis	156	186	28.42	33.88
Rytigynia neglecta	17	16	3.10	2.91
Syzygium guineense subsp. *afromontanum*	11	13	2.00	2.37
Teclea nobilis	40	13	7.29	2.37
Vepris dainellii	476	298	86.70	54.28