Distribution of the Woody Vegetation along the Altitudinal range from Abay (Blue Nile) Gorge to Choke Mountain, East Gojjam Zone, Amhara National Regional State, Northwest Ethiopia.

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ABSTRACT

The distribution of the Woody Vegetation along altitudinal ranges from Abay Gorge to Choke Mountain, East Gojjam Zone of Amhara Regional State, North West Ethiopia.

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Distribution of Woody Vegetation along altitudinal ranges from Abay Gorge to Choke Mountain was conducted in East Gojjam Zone of Amhara Regional State, North West Ethiopia, with aim of assessing floristic composition, species diversity and structure of woody plant species in the study area. Systematic line transect sampling method was applied to collect woody vegetation data. Accordingly, 56 quadrats each with 400 m^2 (20 m X 20 m) at a distance of 50 m. a. s. l. along a transect line for tree and shrubby species and subquadrats of 5 m X 5 m within the main quadrats were laid to record saplings and seedlings of woody plants and soil sample. Vegetation classification was performed by using R Software packages. Four clusters were identified and designated as local plant community types. Each community was named after two or three of the dominant tree or shrub species in the group. Shannon-Wiener diversity index was used to compute species richness and evenness of the communities. Ecological dissimilarity of communities was determined by Euclidean distance. CCA was used to correlate pH and altitude, while FSO was used to correlate environmental factors. DBH, Density, Frequency and IVI were computed to describe the structure of vegetation. A total of 120 woody plant species in 90 genera and 48 families were identified. Fabaceae and Asteraceae were the most dominant families with 16 and 14 species and with 11 and 10 genera each respectively. Shrubs were the dominant life forms. Thirteen endemic species were recorded, from which 4 are new records for FEE. Altitude and soil pH have great impact in vegetation distribution. Future research directions and recommendations were suggested for the sustainable utilization of the vegetation.

Key words/Phrases: Floristic Composition, Plant Community, Species Diversity, Woody Vegetation, Tree, Shrub, Endemic species, Soil pH

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LIST OF ACRONYMS

AACCSA	Addis Ababa Chamber of Commerce Secretariat Association
AAU	Addis Ababa University
BA	Basal Area
CBD	Convention on Biological Diversity
CSA	Central statistical agency
DBH	Diameter at Breast Height
E.G.Z.A.O.C.P.U	East Gojjam Zone Agricultural Office Crop Protection Unit
E.G.Z.O.D.P.U	East Gojjam Zone Organized Development Program Unit
EFAP	Ethiopian Forestry Action Plan
EFAP	Ethiopian Forestry Action Program
ENMSA	Ethiopian National Meteorological Station Agency
EPA	Environmental Protection Authority
ETH	National Herbarium
EWNHS	Ethiopian Wildlife and Natural History Society
FAO	Food and Agriculture Organization
FEE	Flora of Ethiopia and Eritrea
FSO	Fuzzy Set Ordination
GPS	Geographical Position System
IBC	Institute of Biodiversity Conservation
IBCR	Institute of Biodiversity Conservation and Research

IUCN	International Union for Conservation of Nature and Natural Resources
IUFRO	International Union for Forestry Research Organizations
NAP	National Action Plan
NBSAP	National Biodiversity Strategy and Action Plan
NFPA	National Forest Priority Area
NMA	National Meteorological Agency
NMSA	National Meteorological Service Agency
OM	Organic Matter
PCC	Population Census Commission
RD	Relative Density
RDO	Relative Dominance
RED	Relative Euclidean Distance
RF	Relative Frequency
UN	United Nation
UNCCD	United Nations Convention to Combat Desertification

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

Ethiopia is an important regional center for biological diversity due to its wide ranges of altitude, great geographical diversity with high and rugged mountains, flat-topped plateaus and deep gorges, incised river valleys and rolling plains (Ensermu Kelbessa *et al.* 1992; Zerihun Woldu, 1999). The altitude of the country ranges from 110 meters below sea level at the Dallol Depression in the North-East, to the highest peak in the North-West of the country at Mount Ras Dashen, which is 4620 m. a. s. l. (Belachew yirsaw, 2013). Ethiopia, because of its geographical position, ranges of altitude, rainfall pattern and soil variability has an immense ecological diversity and a huge wealth of biological resources (IBC, 2007). These topographic and altitudinal variation helped the emergence of wide ranges of habitats that are suitable for the evolution and survival of various plant and animal species (Zerihun Woldu, 1999; Gete Zeleke 2003). As a result, the country is regarded as one of the most important countries in Africa with respect to endemism of plant and animal species (EWNHS, 1996).

The Flora of Ethiopia and Eriteria included abuout 6000 higher plant species with 10% endemism (Hedberg *et al.*, 2009). Furthermore, woody plant species in the Flora of Ethiopia and Eritrea was estimated to be 1100; out of these about 300 are tree species (Demel Teketay *et al.*,2000).This places Ethiopia in the fifth largest flora in tropical Africa (Eshetu Yirdaw, 2001)Vegetation types in Ethiopia are highly diverse ranging from afro-alpine to desert vegetation (EFAP, 1994). Currently, Friis *et al*. (2011), identified twelve major vegetation types in Ethiopia. From these the Flora area includes *Combretum* - *Terminalia* woodland; Dry Evergreen Afromontane forest; Ericaceous belt and Afro-alpine vegetations.

As result of deforestation, Ethiopia's forest has been declining both in size and species richness (Eshetu Yirdaw, 2001). Due to the continuing encroachment, it is highly probable that the present fragmented vegetations in the highlands of Ethiopia are much more impoverished in terms of floristic diversity than the vegetations which once occupied the same site (Seif Moges and Reddy, 2013).Loss of forest cover and biodiversity due to human-induced activities was a growing concern in many parts of the world (Feyera Senbeta and Demel Teketay, 2003) and East Gojjam is one of the areas with such ecological and environmental problems in Ethiopia.

In the Flora area (East Gojjam), there are no large patches of preserved natural forests, but rather patches of woodlands in the Abay Gorge and Choke Mountain and scattered woody species in the remaining parts of the landscape were indicators of presence of forest in past. Unfortunately, no studies have been made on the distribution of woody plant species in East Gojjam Zone. So that information is gravely important on floristic composition, species diversity and structure of distribution of woody plant species; to provide information and recommendations for the management; sustainable utilization and conservation of the woody plants. By considering such study limitations as initial point, this study paper is intended to assess the composition and distribution of the woody vegetations in the altitudinal range from Abay Gorge (Blue Nile) to Choke Mountain in East Gojam Zone.

1.2. Research Questions

- What is the composition and structural pattern of the woody plant species of the study area?
- What are the community types in the study area?
- What are the patterns of distribution of woody species along some environmental gradients?
- What are the endemic woody plant species in the study area?
- What are the dominant woody plant species in the study area?

1.3. Objectives of the Study

1.3.1 General objective

- To assess the floristic composition, species diversity and structure of the distribution of the woody plant species along altitudinal ranges from Abay Gorge to Choke Mountain.

1.3. 2 Specific objectives

- To document the woody plant species composition in the study area;
- To classify the sample quadrats into plant community types;
- To determine the most dominant woody plant species of the study area.
- To determine endemic woody plant species of the study area.
- To determine the effect of environmental factors (altitude and soil pH) on the distribution of woody plant species.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Floristic Diversity and vegetation types

Ethiopia as a country is known by its large natural and cultural diversity with a wide range of climate, which results from its topography and latitudinal position, and has diverse vegetation types in which diverse flora and fauna exist (Dinkissa Beche, 2011).The variations in latitude have resulted in a wide variation in rainfall, humidity, temperature and exposure to wind (Yohannes Mulugeta, 2013). Moreover, edaphic variations form the basis for the wide biodiversity of the country. This geographical and ecological diversity of Ethiopia, contributed to the high rate of endemism and diversity (Demel Teketay *et al.*, 2004; IBCR, 2009).

The vegetation of the country is very complex and heterogeneous. This complexity of vegetation varies from semi-desert to Afro-alpine type (Friis *et al.*, 2010). Furthermore, the country includes about 6000 higher plant species from which about 10% are endemic (Vivero *et al.*, 2005). According to Demel Teketay *et al.* (2000), the estimate of woody plant species in the Flora of Ethiopia and Eritrea was about 1100; out of these about 300 are tree species. The vegetation of Ethiopia has rich endemic elements (Tewolde Berhan Gebre Egziabher, 1991). For instance, of the total woody plant species, 428 are estimated to be endemic and near endemics. From this, 107 are trees and 321 are shrubs (Vivero *et al.*, 2005).

2.2 Vegetation Types of Ethiopia

A number of authors have contributed to the classification of the vegetation types in Ethiopia. These include Lissanework Nigatu (1987), Tamrat Bekele (1994), Kumilachew Yeshitela (1997), Teshome Soromessa (1997), Sebsebe Demissew (1998) and Zerihun Woldu (1999. Friis *et al.* (2011) indicated that there are twelve major vegetation types in Ethiopia. Of the above vegetation types, the following are found in the study area.

2.2.1 Dry Evergreen Afromontane Forest

The Ethiopian highlands contribute large coverage of land area with Afromontane vegetations, of which Dry Evergreen Afromontane Forests (DAF) form the largest part. It occurs in an altitudinal range of 1800-3000 m, with average annual temperature and rainfall of 14-25°C and 700-1100 (rarely up to 1700 mm), respectively (Friis, 1992; Friis *etal*., 2010). The forests in this vegetation types have greatly diminished due to expansion of agriculture and other interference by people and domestic animals and have been replaced by bush land and scrub in most areas. According to IBCR (2009), dry evergreen montane forest is multi-storeyed and the top storey consists of the taller trees known as "emergent's" because they project above the lower layers. Below the emergent are a layer of shorter trees of various heights forming a more or less continuous canopy; still lower is a stratum of short trees and large shrubs, much less dense than the second stratum. Finally, there is the lowest stratum of shrubs, succulents, and herbs. Epiphytes, lianas and semi-parasites are common (Zerihun Woldu, 1999). About 460 species, subspecies and varieties of woody plants occur in this vegetation type, from these 128 (27.83%) are reported only from this vegetation type. This indicates that this vegetation type is rich with species composition (Friis *et al.,* 2010).

The characteristic emergent species of this vegetation type include *Olea europea* subsp. *cuspidata, Juniperus procera, Prunus africana, Euphorbia ampliphylla, Dracaena* spp. *Carissa* *spinarum, Euclea divinorum, Rosa abyssinca, Mimusops kummel, Ekebergia capensis,* etc (CBD, 2009).

2.2.2 Afroalpine and Subafroalpine Vegetation type

Ethiopia has the largest extent of afro-alpine and sub afro-alpine habitats in Africa (Yalden, 1983). This vegetation type is found on mountains between 3,200 and 4,620m.a.s.l. The area on which the average altitude is greater than 3200 meters above sea level is generally referred to as the Afro-alpine and Sub-afroalpine (Hedberg, 1957). The lower limit of this afro-alpine belt falls at about 3500 m, while the upper limit of vascular plants lies around 5000 m (Hedberg, 1964), and subafroalpine areas ranges between 3200- 3500 meters above sea level. These areas include chains of mountains, mountain slopes and tops of highest mountains in the country.

The characteristic species of this vegetation type includes giant lobelia (*Lobelia rhynchopetalum*), the evergreen tree heather (*Erica arborea*), and shrubby and herbaceous everlasting flowers (*Helichrysum* spp.*)* are few of the species that inhibit this vegetation area.

2.2.3 *Combretum-Terminalia* Woodland vegetation types

This vegetation types occurs between 500 and 1900 m.a.s.l and is characterized by small to moderate-sized tree species with broad leaves, often deciduous, such as *Anogeissus leiocarpa, Stereospermum kunthianum* and species of *Terminalia* and *Combretum* are few of them.

The vegetation in *Combretum-Terminalia* woodland vegetation type has developed under the influence of fire and many of the trees have thick corky bark while the herbs are generally geophytes (IBCR 2009).

2.3 Biodiversity and its threats in Ethiopia

Ethiopia still has a rich diversity important to the world in both domesticated and wild plant and animal species that occur in variable and unique micro and macro-ecosystems (FAO, 1996; NBSAP, 2005). These rich biodiversity of the country is under serious threat from deforestation, land degradation, overexploitation, overgrazing, habitat loss and invasive species (EPA, 1998, Demel Teketay, 2001). In most cases, the major destructive factor of plant diversity is deforestation caused by agricultural expansion and fuel wood scavenging (Ababu Anage, 2009). This could be probably due to an increased human population and their encroachments on natural habitats of every ecosystems on which they depend.

In the context of Ethiopia, most drastic damage has occurred in the natural high forests and their biological resources that have once covered more than 42 million ha (35% of total land area) of the land in the country (IBC, 2007). To see this, the extent of past forest cover on the Ethiopian highlands is evident from the numerous isolated mature forest trees or small patches of forests or woodlands that make conspicuous landmarks on the plateau (Friis, 1992). Large areas with evergreen bush land or farmland mixed with bush land represent formerly forested areas (Friis, 1992). In the current situation, the country is attracting rapid rate of investment for agro-industry expansion and migration of population to fragile ecosystems like Forests. However, almost all of these huge activities were done without proper prior environmental impact assessment. As a result, many relatively irreplaceable forests and forest patches are cleared for different activities like livestock ranches, coffee plantation and tea plantations (Kumilachew Yeshitela, 2001; Yonas Yemishaw, 2001; Getachew Tesfaye and Demel Teketay, 2005). The causes of deforestation and vegetation degradations are many and they are dependent on the type of vegetation, location of vegetation and social and economic circumstances of the people that live in the area.

2.4 Plant Community types

Vegetation cover of a given area has a definite structure and composition (Mueller-Dombois and Ellenberg 1974 and Kent and Coker 1992). In order to have good mental picture of vegetation of an area and to understand distribution of plant species, floristic composition and vegetation community study is essential. Both vegetation structure and floristic composition are usually measured or estimated on the basis of plant community (Mueller-Dombois and Ellenberg, 1974). Consequently, description of plant communities involves the analysis of species diversity, evenness and similarity (Kent and Coker, 1992).

2.5 Diversity Indices

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

2.5.1 Species diversity and richness

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

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

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

Generally, these patterns of plant species diversity have often been noted for prioritizing conservation activities because they reflect the underlying ecological processes that are important for management (Lovett *etal*. 2000).

2.5.2 Measurement of Similarity and Dissimilarity

The notion of community resemblance is central in ecology, and it can be obtained by measuring similarity or dissimilarity of the community (Westhoff and van der Maarel, 1978). Similarity indices measure the degree to which the species composition in quadrats is alike; whereas dissimilarity coefficient assesses which of the two quadrats differ in composition. Sorenson's coefficient of similarity is the most common binary similarity coefficient, because it relies on presence or absence data and also gives more weight to species that are present in both quadrats and less weight to species that are present in only one quadrat. Sorenson's Coefficient is expressed as

$$Ss = 2a/ (2a+b+c) \quad \text{(Kent and Coker, 1992)}$$

Where; Ss = Sorensen's similarity coefficient;

a = Number of species common to both samples;

b = Number of species found only in sample 1;

c = Number of species found only in sample 2.

The other similarity ratio measuring indices is an anonymous 'similarity ratio measuring indices which was introduced by WISHART and CLUSTAN, as a set of classification programmes, was used by Westhoff and van der Maarel, (1978), which is the most commonly used quantitative similarity ratio measureing indices. The general formula for this Similarity Ratio is

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

Where; S= is similarity ratio measure,

$x_{k,i}$ = the value of species k in quadrat i and

$x_{k,j}$ = the value of species k in quadrat j.

2.6 Species Abundance and Frequency

Abundance is the number of individual plants of a given species per unit area. It can be used to show spatial distribution and ranges over time (spatio-temporal variation of species). Frequency is the proportion of quadrats in which a species occurs. It is a measure of the occurrence of a given species in a given area. Frequency indicates how the species are dispersed and is an ecologically meaningful parameter. According to Kent and Coker (1992), it can give an approximate indication of the homogeneity of the quadrats under consideration**.**

2.7 Species Importance Value (SIV) and Dominance

Plant *species* vary in their responses to environmental factors. A given species will have a unique set of tolerances to environmental variables, such as disturbance, pH, Altitude, light, temperature, moisture, and nutrients. At the community level, these differences in tolerances will cause various species to have competitive advantages, depending on the nature of those environmental factors. Therefore, species importance value index permits a comparison of species in a given location and reflects the dominance, occurrence and abundance of a given species in relation to other associated species in an area (Kent and Coker, 1992).

Generally, to develop conservation strategy and plan, species importance value index is a good index for summarizing vegetation characteristics and to rank species for management and conservation practices and to prioritize them.

2.8 Endemism of plant species

Endemism is the ecological state of a species being unique to a defined geographic location, such as an island, country or other defined zone, or habitat type. Furthermore, endemic plants are foundations of the native ecosystems or natural communities (Deemson, 2011). Different factors can contribute to endemism. These include physical, climatic and biological factors. According to Deemson (2011), endemics can easily become endangered or extinct if their restricted habitat changes, particularly but not only due to the actions of man, including the introduction of new organisms.

Ethiopia is an important regional centre of biological diversity and the flora and fauna have rich endemic elements (WCMC 1992). The country has the fifth largest flora in tropical Africa (Eshetu Yirdaw, 2001). The great diversity of ecological conditions, mainly determined by topography, has created environments conducive for the development of a wide variety of flora (EPA, 1997). Endemism is particularly high in the afroalpine vegetation zone and in the dry montane forest and grassland complex of the plateau (EWNHS, 1996). In general, the afromontane region is one of the seven centers of endemism of the afrotropical realm (Huntley 1988).

CHAPTER THREE

3. MATERIALS AND METHODS

3. 1. Description of the Study Area

3.1.1. Location

The study was conducted in six districts (Figure 1), in East Gojam Administrative Zone of Amhara Regional State, between 1056 and 3906 m altitudes. This zone is found in the Northwestern part of Ethiopia at about 299 km from Addis Ababa and has a total area of 14705.36 sq. km, with an altitude ranging from 800 to 4070 m.a.s.l. The six districts (Woreda's) are located between Abay Gorge (10°08.190' N and 038°20.145'E) and Choke Mountain (10°64.142'N and 037°83.593'E). The nearest large towns for Choke Mountain are Bahir Dar to the North and Debre Markos to South, while Dejen and Gohatsihon are the nearest towns to Abay Gorge to North and South respectively.

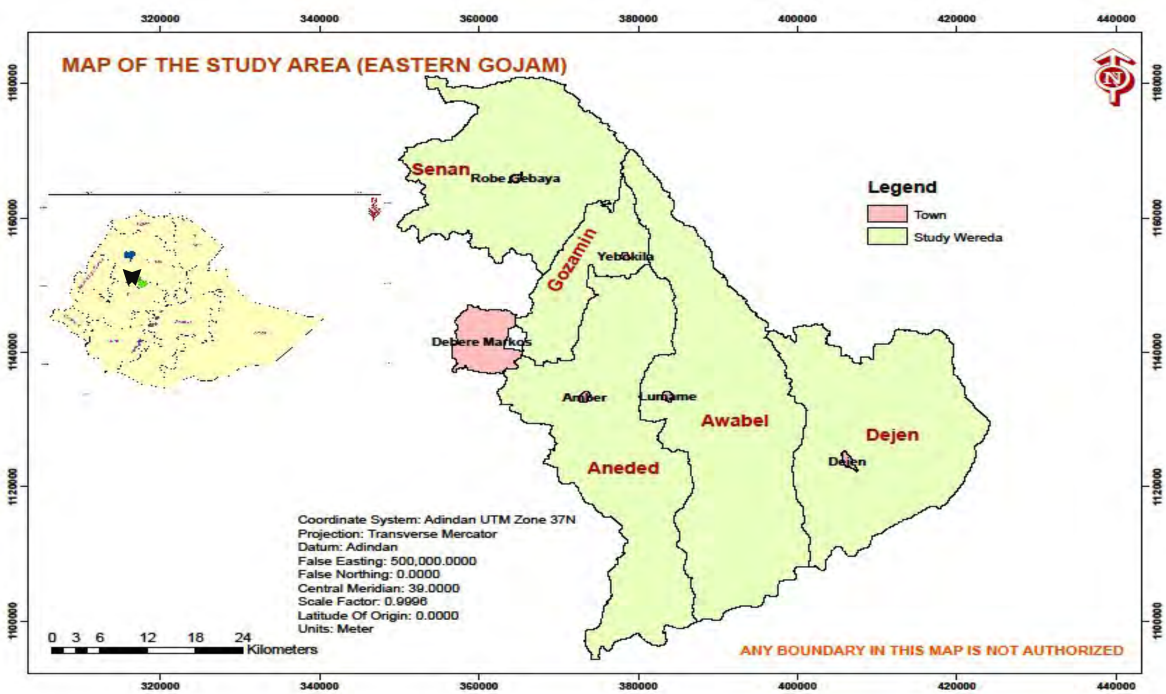


Figure 1: Map showing where the study was conducted (the six districts) in East Gojjam Administrative Zone, North Western Ethiopia.

3.1.2 Topography

East Gojjam Zone is characterized by mountains including Choke Mountain, plateaus (Yetnore, Awabal and Anaded) and Gorges (Abay Gorge and Gorgsin and around Sinana woreda). The study area occours in the altitudinal ranges between 1000 to 4070 m a.s.l. starting from the Abay River bridge (Gohatsion and Dejen) and Choke Mountain respectively (GPS reading during field work). The zone is estimated to be 48% mountainous, 12% rugged and 40% gentle sloped (Belay Simane *et al.*, 2013).

3.1.3 Demographics

According to the recent senses in Ethiopia (CSA, 2007), East Gojjam Zone has a total population of 2,153,937, of whom 1,066,724 are Men and 1,087,221 are women; with an area of 14705.36 square kilometers, and this zone has a population density of 153.80/km^2. The urban populations account to 213,568 (9.92%) of the inhabitants. The largest ethnic group reported in this zone was Amhara (99.82%), and all the other ethnic groups combined were about 0.12% of the total population. Amharic is primary language spoken by the total population. With respect to religion, 97.42% of the total population was followers of Ethiopian Orthodox Christianity, and the rest 2.49% were followers of other religions.

However, the total population of East Gojjam zone in the year 2013 was about 2,441,749 of whom 1,208,833 are men and 1,232,916 are Women (unpublished report of E.G.Z.O.D.P.U., 2013). According to the same report, the population of this zone increased by 287,182 from that of CSA 2007 report.

Moreover, the total population of the six wordas (Anaded, Awobal, Dabre Markos, Dejan, Gozamin and Sinan) were about 652539, from this 56329 (8.63%) were urban dwellers and the rest 596,210 (91.37%) live in rural areas (unpublished report of E.G.Z.O.D.P.U., 2013). These populations of the area are about 26.72% of the total population of East Gojjam Zone.

3.1.4 Soil

The study area is covered by different soil types. According to Belay Simane *et al.* (2013), areas in the lower altitudes (around Abay Gorge) are covered with Leptosols and Combisols, while areas in the midland plains such as Dejen are covered with Vertisols; still other areas around Awabel, Aneded and Gozamin are covered with Nitosols and Alisols; areas around midland and slopping lands are equipped with Nitosols, Alisols and Leptosols and finally, the hilly and mountainous highlands (Sinan or Choke mountain) are covered with Leptosols and Luvisols.

3.1.5 Climate and Agro-climatic Zones

The data of rainfall and temperature for the study area were obtained from National Meteorological Agency (NMSA, 2014). The average 13 years mean maximum and minimum annual temperatures were about 30.5^0C and 9.9^0C for Abay Gorge, 26.2^0C and 8.8^0C for Debre Markos respectively. The mean annual rainfall values for the study areas were 1223 and 1322 for Abay Gorge and Debre Markos respectively (NMSA, 2014) (Figure 2 and 3).

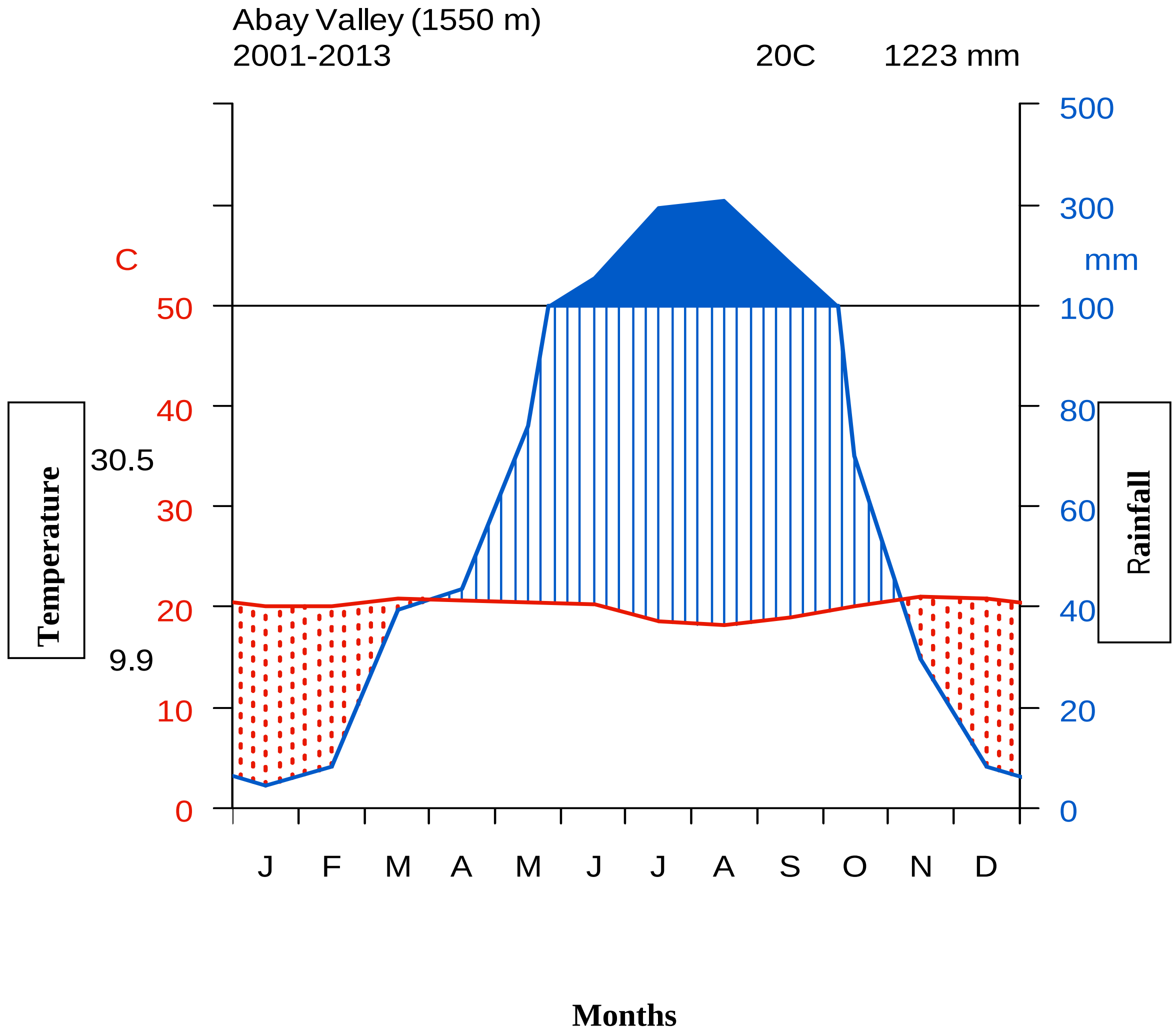
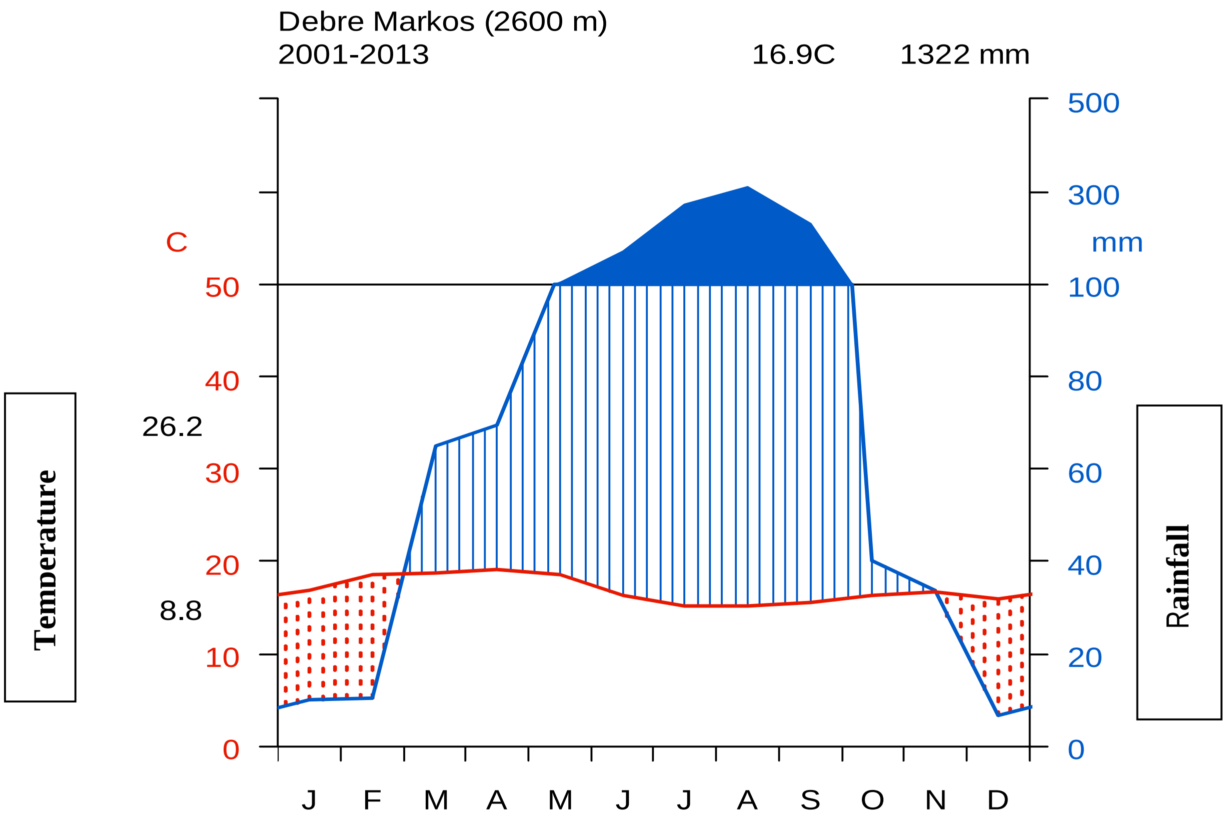


Figure 2: Climate diagram of the Abay Gorge, showing rainfall distribution and temperature variation from 2001 to 2013. [Data source: National Meteorological Service Agency (NMSA, 2014)].



Months

Figure 3: Climate diagram of the Debre Markos, showing rainfall distribution and temperature variation from 2001 to 2013. [Data source: National Meteorological Service Agency (NMSA, 2014)].

The study area is categorized into four agro climatic zones, and these agro-climatic zones include Cool and humid (Dega), cool sub-humid (Woinadega), Warm semiarid (Kola) and cold and moist (Wurch) (Belay Simane *et al.*, 2013).

Moreover, according to the personal communication and unpublished reports of the East Gojjam Zone Agricultural Office, each of the Agro-climatic zones encompass Cool and humid, cool sub-humid, Warm semiarid and cold and moist with 45 %, 35 %, 18 % and 2 % respectively (Unpublished reports of E.G.Z.A. C.P.U., 2013).

3.1.6. Land use, Trade, Agriculture and Tourism.

The proportion of built up area, cultivated land, forest land, grassland and shrub and bush land in Abay Gorge and Choke Mountain is 1.29%, 70.43%, 1.08%, 23.2% and 4.0% respectively (Table 1) (EGZODPU, 2013). The Forest land indicated above is mostly plantation forests except few remnant patch of Natural forest (Personal observation during data collection and Personal communication with local peoples). These natural Forest patches and plantation forests are protected by the local government and communities (unpublished report of E.G.Z.O.D.P.U, 2013).

There are wholesale, some retail traders and open markets were available in towns of each woerda. Different crops like: Sorghum species in low altitudinal range, Teff (*Eragrostis tef*), in low and medium altitude, barely (*Hordeum vulgare)*, horse bean (*Vicia faba)*, and Potato (*Solanum tuberosum)* are important subsistence and cash crops in the respective Districts. Honey production is also practiced in remnant vegetation patches in different woreda's by small organized youth or Micro groups (personal communication with E.G.Z.A.C.P.U.). With regard to tourism, Abay River and its Renascence Bridge, topography of Abay Gorge, different historical Churches, topography of Arat Mekera Kir and Nature of Choke Mountain are the major tourist attraction sites(Personal observation during data collection).

Table 1: Land use pattern in the six districts or Woreda's, with in the study area

Land use Type	Area in hectare with respective Woredas					
	Dejen	Guzamin	Senan	D. Markos	Awabel	Aneded
Built Up Area	911.61	1595.95	113.67	806.27	1017.33	442.5759
Cultivated land	32831.93	86359.17	25035.14	4872.56	68196.97	49602.73
Forest land	219.36	65.66	1724.874	102.26	1516.50	381.50
Grassland	17936.48	28986.50	14162.16	801.46	8778.97	17175.41
Shrub & Bush land	10168.01	115.75	2612.21	-	861.86	162.18
Total	62067.39	117123.04	43648.06	6582.5	80371.64	67764.40

Source: Unpublished report of E.G.Z.O.D.P.O., (2013)

3.1.7 Vegetation of the Study Area

Topography of east Gojam zone is wide, and these topographic variations compiled with climatic variability resulted in different vegetation types. Among the 12 vegetation types occurring in Ethiopia (Friis et al., 2011), three vegetation types are found in the study area. These are Afro-alpine and sub-afroalpine vegetations, Dry Evergreen Montane Forest and *Combretum-Terminalia* Woodland (Friis et al., 2011).

The first vegetation type (Afro-alpine and sub-afroalpine) is found in Sinan woreda around Choke Mountain. Woody plant species, *Erica arborea*, *Hypericum quartinianum, Lobelia* *rhynchopetalum, Echinops longisetus, Europs pinifolius* and *Helichrysum citrispinum* are common woody plants that are found in the area (Friis *et al*., 2011).

Second vegetation type is Dry Ever green Afromontane Forest is grounded here. According to Tamrat Bekele (1994), the Ethiopian highlands contribute to more than 50 % of the land area with Afromontane vegetation, of which dry montane forests form the largest part. This Dry Ever Green Mountain Forest vegetation type roughly occurs between 1500m and 3200m altitudinal range (Zerihun Woldu 1999). The Dry Evergreen Montane Forest and Evergreen Scrubland vegetations are the characteristic vegetation types of this ecosystem. These Dry evergreen montane vegetation areas are under severe pressure and threat of destruction caused by deforestation for wood products (especially fuel wood extraction), fire, encroaching agriculture, plantation of Eucalyptus and overgrazing (CBD, 2009). Due to this high anthropogenic effect, the forests of study area have been lost but remnant plants around the Churches, inaccessible areas, communal shade trees and large trees on grazing and farm lands are observed. Some of the woody plant species that characterize this vegetation typearea include *Juniperus procera, Hagenia abyssinica, Acacia abysinica, Cordia africana, Ficus sur, Erythrina brucei, Calpurnia aurea, Prunes africana, Carissa spinarum, Rosa abyssinia, Dombeya torrida* and *Maytenus arbutifolia (*Friis *et al*., 2011).

The 3rd vegetation type that is found in the study area is *Combretum-Terminalia* Woodland.This vegetation type is characterized by *Combretum spp., Anogeissus lieocarpa, Sterospermem kuntianum and Albizia spp. (*Friis et al., 2011*).*

Figure 4: Part of vegetation around Choke Mountain.

Figure 5: Vegetaion of Choke Mountaion on the other side

Figure 6: Natural Forest Patch between Gozamin and Sinan Woreda.

Figure 7: Vegetation close to Abay River 200 km. from Addis Ababa. The upper parts (over 2000 m) reperesents the dry Afromontane Forest and grassland while the lower part close to river reperesents the *Combretum-Terminalia* wood land.

3.2 Materials

The materials that were used during the actual plant data collection in the field are plant press, secateurs, plastic bags, GPS, digital camera, rolling meter, scotch tape, plastic rope with different size, news paper, pH meter, digger for soil sample, distilled water, glass rod and beaker.

3. 3 Methods

3.3.1 Reconnaissance Survey

Reconnaissance survey was conducted in mid November, 2013 to have familiarity with the vegetation, topography of the area, identify direction of the transect line; have tell for altitudinal gradients and to familiarize with woody plant species of the area.

3.3.2 Sampling Design

Following the reconnaissance survey, single line transect was laid along the altitudinal gradient starting from the bottom ridge in the Abay Gorge to the top of Choke Mountain. Systematic sampling following Kent and Coker (1992) and Muller-Dombois and Ellenberg (1974) were used in this study. The first sampling quadrat was located at the base of the mountain range, and subsequent quadrats were established at 50 m. a. s. l. intervals along transect using GPS. Fifty six quadrats with a size of 20 m x 20 m (400 m^2) were delimited at interval of 50 m in altitude along altitudinal gradients between each quadrats, and sub-quadrats of 5m x 5m (25m^2) were also delimited at the four corners and at the center of large quadrat for counting seedlings and saplings. The sub-quadrats of 5m x 5m were also used for collecting soil samples (Figure 8).

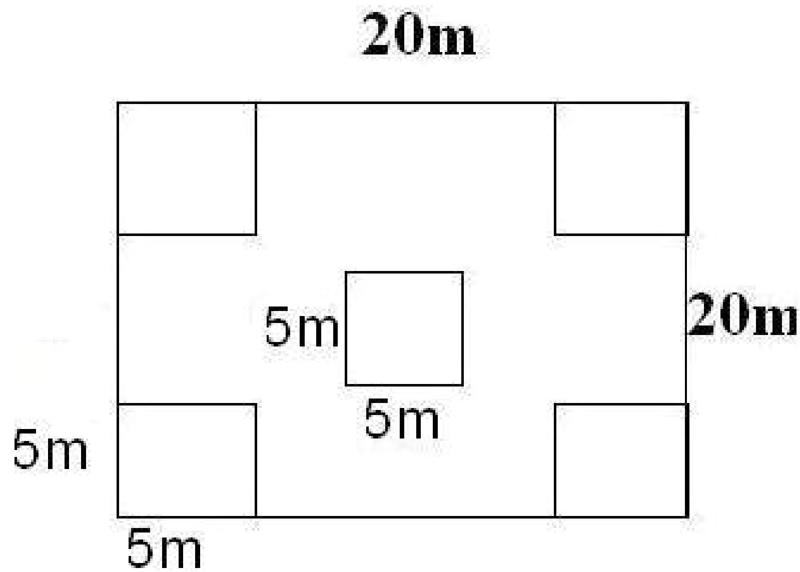


Figure 8: Sampling design for woody plant data collection

3. 3. 3 Vegetation Data Collection

After sampling design, data collection on the woody plant species was carried out. A complete list of woody plant species from each quadrat (20 m x 20m) were recorded and percent cover values for each species were estimated and later converted to the Braun-Blanquet 1-9 scale as modified by Van der Maarel (1979). Saplings and seedlings of woody plant species in sub-quadrats ($25m^2$) were recorded. During data gathering the physiographic variables such as altitude, latitude and longitude were measured for each quadrat by using GPS. Plant specimens encountered in each quadrat were collected and brought to the National Herbarium of Ethiopia (ETH), Addis Ababa University for identification, verification and reservation.

3.3.4 Structural data collection

All woody plant species with DBH greater than 2.5cm (circumference greater than 7.8cm) at breast height or 1.3m above ground were counted as tree or shrub following Feyera Senbeta and Demel Teketay (2001) and latter these values were converted in to diameter to calculate the basal area of the species. Those having a value less than 2.5 cm were considered as sapling and seedlings. The heights of tree and shrub species above 3 m were visually estimated and recorded. For the purpose of this study “seedlings”, “saplings” and “mature trees/ shrubs” were defined as plants with heights less than 1 m, 1-3 m and greater than 3 m respectively. Percentage of cover abundance was estimated and later converted into modified Braun Blanquet scale. The 1-9 modified Braun-Blanquet scale was used following van der Maarel (1979). Accordingly, the scale represents:

1 = Rare, generally one individual,

2 = Occasional or sporadic with less than 5% cover of the total area,

3 = Abundant, with less than 5% cover of total area,

4 = Very abundant, with less than 5% cover of the total area,

5 = 5-12% cover of the total area,

6 = 12.5 -25% cover of total area,

7 = 25-50% cover of the total area,

8 = 50-75% cover of the total area, and

9 = 75-100% cover of the total area

The Diameter at Breast Height (DBH), basal area, tree density, frequency and important value index were used for description of vegetation structure in the study area.

A. Diameter at breast height (DBH):DBH measurements were taken at about 1.3m above the ground by using measuring tape (Figure 5), for those woody plants having circumferences greater than 7.8 cm (> 2.5cm diameter) and later the diameter is calculated from circumference (C) = π D where D is diameter at breast height.

B. Basal area (BA): Basal area is the outline of a plant near the surface of the ground. It can be expressed in square meter/hectare (Mueller-Dombois and Ellenberg, 1974). Basal area is also used to calculate the dominance of species.

$BA = \pi (D/2)^2 = (DBH/2)^2 \times 3.14$, where D or DBH is diameter at breast height.

Figure 9: Basal area measurement in the field during Data collection

C. Density: Density is a count of the numbers of individuals of a species within a quadrat (Kent and Coker, 1992). It is closely related to abundance but more useful in estimating the importance of a species. Counting is usually done in each quadrat in the area under study. Afterwards, the sum of individuals per species in all quadrat is calculated in terms of species density per convenient area unit such as a hectare (Mueller-Dombois and Ellenberg, 1974).

3.3.5 Environmental Data collection

The environmental parameters recorded in this study were altitude and soil pH. Altitude was measured by GPS. Two soil samples were taken from each quadrats one from 0–10 cm (topsoil) and the other from 10–30 cm depth (subsoil). The soils samples from both depths were taken from the four corners and one from the center of the main-quadrat. The soils taken from these five sub-quadrats in the main quadrat were mixed together and brought to Eco-Physiology laboratory of Addis Ababa University for analysis.

3.3. 6 Data analysis

3.3.6.1 Vegetation data Analysis

Hierarchical cluster analysis is one of the most commonly used multivariate techniques to analyze community ecological data. It helps to group a set of observations (vegetation samples) together, based on their attributes or floristic similarities (Kent and Coker, 1992). For this study, Agglomerative hierarchical classification for cluster analysis using similarity ratio as a resemblance index and Ward's method as clustering technique was performed by using appropriate R programs developed by Zerihun Woldu. R is a free software programming language, and software environment for statistical computing and graphics. The R language is widely used among statisticians and data miners for developing statistical software and data analysis (R core Team, 2013).

For this, the similarity ratio measuring indices is (Westhoff and van der Maarel, 1978), which is the most commonly used quantitative similarity measuring index. The general formula for this Similarity Ratio is

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

Where; S = is similarity measure,

$X_{k,i}$ = the value of species k in quadrat i and

$X_{k,j}$ = the value of species k in quadrat j.

Moreover, Synoptic table of the results of the hierarchical agglomerative cluster analysis was produced by using the cluster identifications to compute mean values of the cover abundance of the species in the respective clusters. For this, R Program was used to produce table from simultaneous classification of sites and species (Venables *et al*. 2010). The table mentioned previously is produced by mean values of the species cover abundance of cluster groups, and its values are general summaries of the products of species frequency and average cover abundance values (mean frequency x mean cover-abundance) (van der Maarel *et al*., 1979).

3.3. 6.2 Diversity and Dissimilarity/Distance Indices

Biological diversity can be quantified in different ways (Colwell and Lees, 2000).The two main components to measure diversity of species are species richness and species equitability or evenness. Thus, species richness is the number of species within the community and species equitability is how even the numbers of individual species within the community are. The index of species richness has a great importance in assessing taxonomic, structural and ecological value of a given habitat, and evenness is used to measure abundance of different species in the area and that makes the richness of the area. The product of both indices (species richness and evenness) helps to know the diversity of species in the area.

Shannon-Wiener diversity index is the most popular measure of species diversity, because it accounts both for species richness and evenness, and this Shannon-Wiener diversity index is not affected by sample size (Kent and Coker, 1992; Krebs, 1999). Therefore, Shannon-Wiener diversity index, species richness and Shannon's evenness were computed to describe the diversity of the community types identified. These, Shannon-Wiener diversity index was calculated as follows.

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

- H'= Shannon Diversity Index,
- S = the number of species,
- P_i= the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of total cover and
- ln = log $base_n$

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

- **J**= Evenness,
- **H**' = Shannon-Wiener diversity index and **H'max** = **lns** where **s** is the number of species.

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

Inter and intra cluster distance is used to measure the distance between communities and the distance of the quadrates within a single community respectively. For this, Euclidean distance measuring method is an appropriate method to measure such distances in vegetation ecology, because it is the geometric distance between two objects (or subjects, cases) (Bailey 2008). Generally, its matrices help to provide information on the ecological distance between all pairs of sites within data (Bailey 2008). Generalized formula for this Euclidean distance is:

$$ED_{ij} = \sqrt{\sum (y_{k_i} - y_{k_j})^2}$$

Where: - EDij = Euclidean distance between quadrats **i** and **j**, and

y_{ki} = abundance of k^{th} species in quadrat **i**

ykj = abundance of k^{th} species in quadrat **j**

3.3. 6.3 Structural data analysis

The structure of the vegetation was described by using frequency distributions of DBH and Importance value index (IVI). Tree or shrub density and basal area values were computed on hectare basis. Importance value indices (IVI) were computed for dominant woody species based on their relative density (RD), relative dominance (RDO) and relative frequency (RF) to determine their dominance (Kent and Coker, 1992). The following structural parameters were calculated following Mueller-Dombois and Ellenberg (1974).

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

- Relative Density (RD) = $\frac{\text{The number of all individuals of a species}}{\text{The total number of all individuals;}}$ X 100
- Relative Frequency (RF) = $\frac{\text{Frequency of a species}}{\text{Total frequency of all species}}$ X100
- Relative Dominance (RDO) = $\frac{\text{Total basal area of all individuals of a species}}{\text{Total basal area of all species}}$ X 100
- Basal area (BA) was calculated using DBH as, BA = $\pi D^2/4$, where, $\pi = 3.14$; D is diameter at breast height.

Circumference at breast height was converted in to diameter at breast height by using the formula $C = 2\pi r$ and $R = C/2\pi$ or $2R = D = C/\pi$. Where:- C = Circumference at the breast height; R = radius of the tree $\Pi = 3.14$ and D = Diameter at breast height

3.3. 6.**4 Environmental data Analysis**

The environmental parameters included in this study are altitude and soil pH. The average values of these environmental variables were calculated. Composite samples of soil were air dried and passed through 2mm sieve prior to analysis.

Determination of pH of soil was done by following appropriate procedures of (Allen *et al*., 1974). First, soil was suspended in 1:1 soil to distilled water ratio by dissolving 20g of soil in 20ml distilled water. The contents were stirred occasionally with glass rod in a 50ml beaker (plastic cup) and allowed to settle for 30 minutes. Prior to measurement of pH, the pH meter was brought to the lab and, standardized with a known buffer solution (pH 4:00 and pH 7:00).

Finally, the pH of suspended soil water-solution was measured by using JENWAY Model 3345 PH meter. These obtained or measured values of the soil pH were used for analysis of Environmental impact on woody vegetation.

The relationship between environmental variables (altitude and soil pH) with the quadrats was determined using Canonical Correspondence Analysis (CCA) which is an appropriate meted for this purpose.

Moreover, the relationships of some environmental variables - soil pH and altitude - were determined using fuzzy set ordination. This fuzzy set ordination software helps to computes a set for samples along in a specified environmental or experimental gradient based on sample similarities and gradient values as weights (David 2013). The fuzzy set memberships represent the degree to which a sample is similar to one end of the gradient while not similar to the other, and the axes combine floristic information with information on some of the environmental variables.

CHAPTER FOUR

4. RESULTS

4.1. Woody Plant Species Composition

A total of 120 woody plant species belonging to 48 families and 90 genera were identified from the study area (Appendix2). From the total number of plants recorded, 119 species were angiosperms and the remaining one was a gymnosperm. Of these 119 identified woody angiosperm species 118 (99.16 %) were dicots and the remaining one (0.84%) was a monocot. Of these, 112 woody plant species were encountered within the quadrats, but the remaining 8 species were recorded outside the quadrat. So, analysis of vegetation was based on these 112 woody plant species that were collected from the quadrats. Of all the families, Fabaceae was the most dominant family contributing 16 (14.29%) species, followed by Asteraceae 14 (12.5%) species to the total.

The next dominant family was Tiliaceae with 5(4.46%) species followed by Acanthaceae, Capparidaceae, Euphorbiaceae, Lamiaceae, Rosaceae and Solanaceae each with 4(3.57%) species. Boraginaceae, Celastraceae, Moraceae, Myrsinaceae and Sapindaceae were represented by three species each; Combretaceae, Oleaceae, Ranunculaceae and Sterculiaceae were represented by two species each and the remaining 30 (62.5%) families were represented by one species each (Table two).

At generic level, the families Fabaceae and Asteraceae were represented by 11 (12.22%) and 10 (11.11%) genera each respectively. Euphorbiaceae, Lamiaceae and Rosaceae were represented by 4 (4.44%) genera, followed by Boraginaceae, Combretaceae, Oleaceae, Solanacea and

Tiliaceae each represented by two genera. The remaining 33 (36.33%) families were represented by one genera each.

The woody plant species *Inula confertiflora*, *Mikaniopsis clematoides* and *Senecio myriocephalus* from the family Asteraceae; *Leucas abyssinica*and *Maerua pseudopetalosa* from the family Lamiaceae and Capparidaceae respectively were not recorded in the published books of Flora of Ethiopia and Eritrea; hence they are new records for the flora area (Gojjam).

Table 2: Woody plant species families with their respective number of genera and species

Family	No. of genera	%	No. of spp.	%
Acanthaceae	3	3.33%	4	3.57%
Anacardiaceae	1	1.11%	1	0.89%
Apocynaceae	1	1.11%	1	0.89%
Asclepiadaceae	1	1.11%	1	0.89%
Asparagaceae	1	1.11%	1	0.89%
Asteraceae	10	11.11%	14	12.5%
Bignoniaceae	1	1.11%	1	0.89%
Boraginaceae	2	2.21%	3	2.68%
Capparidaceae	3	3.33%	4	3.57%
Celastraceae	1	1.11%	3	2.68%
Combretaceae	2	2.22%	2	1.79%
Cupressaceae	1	1.11%	1	0.89%
Ebenaceae	1	1.11%	1	0.89%
Ericaceae	1	1.11%	1	0.89%
Euphorbiaceae	4	4.44%	4	3.57%
Fabaceae	11	12.22%	16	14.29%
Hypericaceae	1	1.11%	1	0.89%
Icacinaceae	1	1.11%	1	0.89%
Lamiaceae	4	4.44%	4	3.57%
Lobeliaceae	1	1.14%	1	0.89%
Loganiaceae	1	1.11%	1	0.890%
Malvaceae	1	1.11%	1	0.89%
Meliaceae	1	1.11%	1	0.89%
Melianthaceae	1	1.11%	1	0.89%
Moraceae	1	1.11%	3	2.68%
Myricaceae	1	1.11%	1	0.89%
Myrsinaceae	3	3.33%	3	2.68%
Olacaceae	1	1.11%	1	0.89%

Oleaceae	2	2.22%	2	1.79%
Oliniaceae	1	1.11%	1	0.89%
Phytolaccaceae	1	1.11%	1	0.89%
Pittosporaceae	1	1.11%	1	0.89%
Poaceae	1	1.11%	1	0.89%
Polygonaceae	1	1.11%	1	0.89%
Ranunculaceae	1	1.11%	2	1.79%
Rhamnaceae	1	1.11%	1	0.89%
Rosaceae	4	4.44%	4	3.57%
Rubiaceae	1	1.11%	1	0.89%
Rutaceae	1	1.11%	1	0.89%
Santalaceae	1	1.11%	1	0.89%
Sapindaceae	3	3.33%	3	2.70%
Simaroubaceae	1	1.11%	1	0.89%
Solanaceae	2	2.22%	4	3.57%
Sterculiaceae	2	2.22%	2	1.79%
Thymelaeaceae	1	1.11%	1	0.89%
Tiliaceae	2	2.22%	5	4.46%
Urticaceae	1	1.11%	1	0.89%
Verbenaceae	1	1.11%	1	0.89%
Total	90	100	112	100

Among the total woody plant species, 65(58.04%) were shrubs, 33(29.46%) were trees, 10(8.93%) were woody climbers/lianas and the rest 4(3.57%) were tree/shrubs in growth form composition. Shrubs occupied the highest proportion followed by trees and woody climbers (Figure 10).

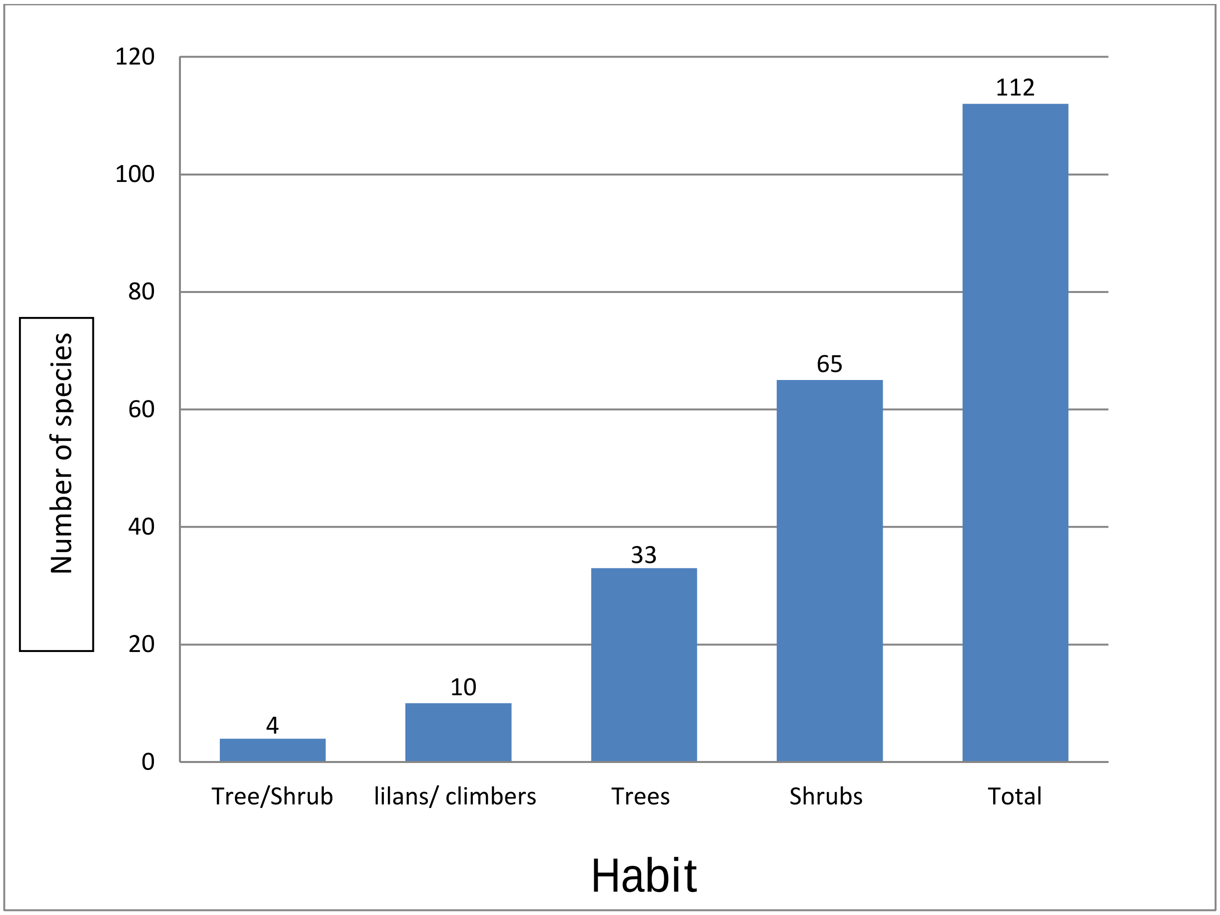


Figure 10: Growth forms of woody plant species from the study area (Abay Gorge to the Choke Mountain).

4.2 Endemism

In the Altitudinal gradient between Abay Gorge and Choke Mountain, a number of woody plant species that are endemic to Ethiopia were recorded during the study period. These endemic species to Ethiopia were identified based on the published Flora volumes. The identified endemic species and distribution of each taxon is given in table three. Accordingly, 13 endemic woody plant species have been recorded from the vegetation area, of these 4 (*Inula confertiflora, Mikaniopsis clematoides, Senecio myriocephalus* and *Leucas abyssinica)* are new records for the Flora region (Gojjam). Of all the recorded endemic woody plant species in the study area

Asteraceae is dominant with 61.54%, while the rest five species are represented by a single species.

Table 3: Endemic taxa recorded from the study area, and their respective family, distribution and habit.

No	Scientific name	Family	Distribution	Habit
1	*Acanthus sennii*	Acanthaceae	GD, GJ, WG, SU, HA, AR, BA, KF, GG and SD	S
2	*Echinops longisetus*	Asteraceae	GD, GJ, WU, SU, WG, AR, HA, BA, KF, GG and SD	S
3	*Erythrina brucei*	Fabaceae	WU, WG, GJ, SU, BA, HA, IL, KF, GD, GG and SD	T
4	*Europs pinifolius*	Asteraceae	WU, GJ, SU	S
5	*Inula confertiflora*	Asteraceae	WU, SU, HA, BA and AR	S
6	*Lagara tomentosa*	Asteraceae	EW, TU, GJ, SU, SD and HA	S
7	*Leucas abyssinica*	Lamiaceae	TU, GD, GG, SD and BA	S
8	*Lippia adoensis*	Verbenaceae	TU, GJ, SU, AR, HA, KF and GG	S
9	*Mikaniopsis clematoides*	Asteraceae	TU, WU, SU, AR, KF, BA & HA	S
10	*Senecio myriocephalus*	Asteraceae	TU, GD, WU, SU, KF, HA, BA, SD and AR	S
11	*Solanecio gigas*	Asteraceae	GD, GJ, WU, SU, BA, KF and IL	S
12	*Vernonia leopoldii*	Asteraceae	TU, GD, GJ, SU, WG, KF, & HA	S
13	*Lobelia rhynchopetalum*	Lobeliaceae	GD, GJ, SU, AR, BA and HA	S

* SD - Sidamo, AR- Arsi; BA-Bale; GD- Gonder; GG - Gamo Gofa; GJ- Gojam; WU- Welo; WG –Welega; HA-Harerge; KF-Kefa; IL-I1ubabor; TU-Tigray; SU-Shewa (All regions were adopted from FEE).

4.3 Plant Communities in Abay Gorge and Choke Mountain

Out of 120 identified woody plant species only 112 woody plant species were used in vegetation classification into community together. Four community types were recognized or identified based on Cluster analysis of vegetation data (Figure 11). The name for each community types were given after two dominant woody species (trees and /or shrubs) occurring in each group using the relative magnitude of the highest mean cover abundance within the cluster (Table 4). A list of the community types along with their synoptic-cover abundance values of the species were given in the Table three. The four different types of classified communities were described as follows.

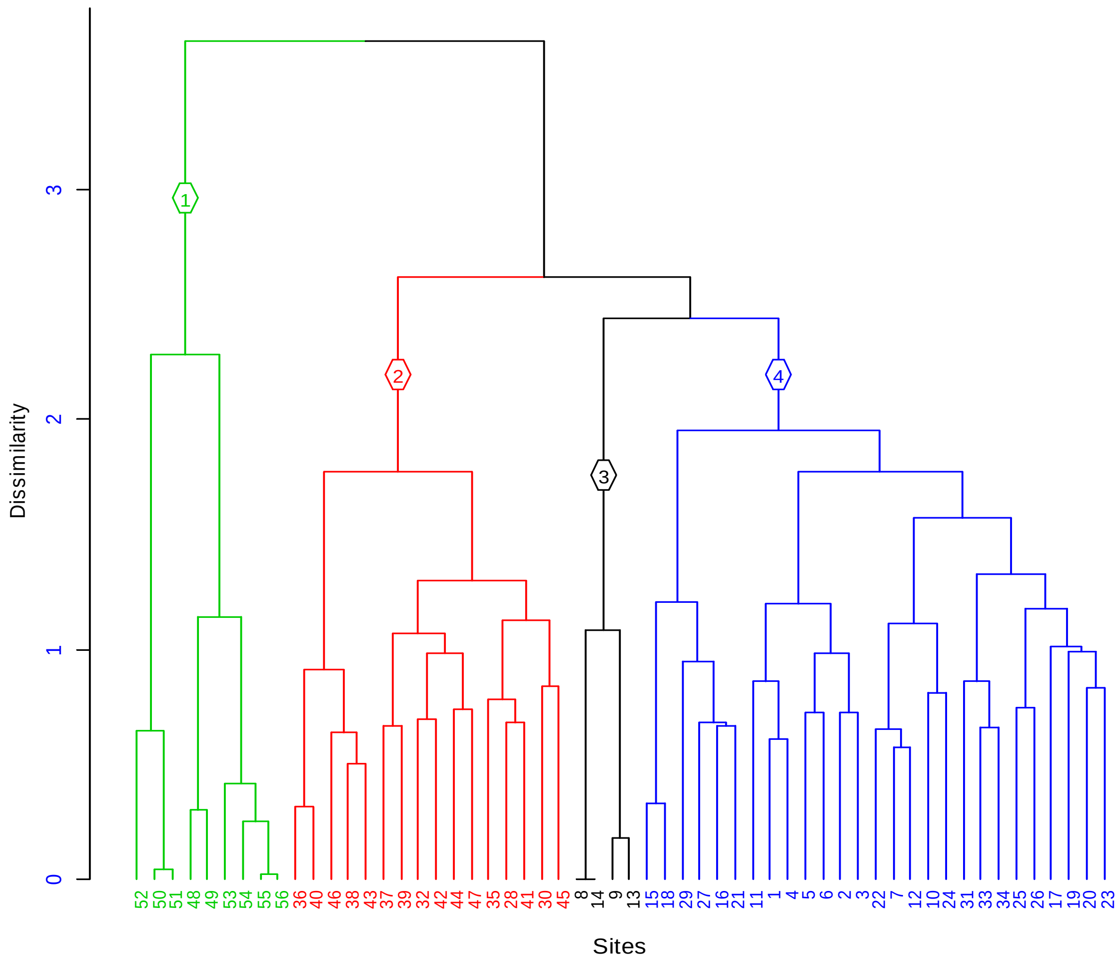


Figure 11: Dendrogram of the vegetation data obtained from hierarchical cluster analysis of vegetation of the study area. Each community is represented by Arabic number.

❖ Communities (clusters) contain the following plots:-

C1:- Plots 48, 49, 50, 51, 52, 53, 54, 55 and 56.

C2:- Plots 28, 30, 32, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46 and 47

C3:- Plots 8, 9, 13 and 14

C4:- Plots 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29, 31, 33 and 34

Table 4: Synoptic cover abundance values for species having synoptic value greater than 0.5 at least in one community type. (Values in bold refers to occurrences as dominant species).

Species	C 1	C 2	C3	C4
Helichrysum citrispinum	**3.78**	0	0	0
Europs pinifolius	**2.56**	0	0	0
Echinops longisetus	**1.44**	0	0	0
Lobelia rhynchopetalum	**1.11**	0	0	0
Rubus steudneri	**0.89**	0	0	0
Erica arborea	**5.89**	0	0	0
Hypercum quartinianum	**4.22**	0	0	0
Hagenia abyssinica	**2.56**	0.69	0	0
Olea europaea subsp. *cuspidata*	0	1.38	0	0
Mikaniopsis clematoides	0	0.75	0	0
Discopodium penninervium	0.56	1.12	0	0
Buddleja polystachya	0	1.62	0	0
Urera hypselodendron	0	0.50	0	0.37
Clematis hirsuta	0	0.69	0	0
Erythrina brucei	0	1.88	0	0
Phytolacca dodecandra	0	**2.69**	0	0.11
Clematis simensis	0.33	0.56	0	0.33
Arundinaria alpina	0	0.69	0	0
Acanthus sennii	0	0.5	0	0
Dombeya torrida	0	**2.06**	0	0.67
Juniperus procera	0	1.12	0	0.3
Tamarindus indica	0	0	**5.5**	0.89
Albizia isenbergiana	0	0	**3**	0.81
Dichrostachys cinerea	0	0	0.75	0.89
Croton macrostachyus	0	0	0	**1.33**
Acacia abyssinica	0	0	0	**1.37**
Combretum collinum	0	0	0	0.52
Grewia bicolor	0	0	0	**1.04**
Anogeissus leiocarpus	0	0	0	0.71
Ficus glumosa	0	0	0	0.67
Grewia ferruginea	0	0	0	0.67
Calpurinia aurea	0	0.31	0	0.56
Senna singueana	0	0	0	0.56
Justicia schimperiana	0	0	0	0.67

Ekebergia capensis	0	0	0	0.96
Bersama abyssinica	0	0	0	0.67
Brucea antidysenterica	0	0	0	0.59

4.3.1 *Erica arborea - Hypercum quartinianum* Community type one

This community is located in the altitudinal range between 3506 and 3906 m. a. s. l. and it is represented by 12 species in 9 quadrats. The community is dominated by *Erica arborea and Hypercum quartinianum,* both are tree/shrubs. *Helichrysum citrispinum* and *Europs pinifolius* are the dominant species in the shrub layer. *Hagenia abyssinica* is the only tree in this community, while *Echinops longisetus, Lobelia rhynchopetalum, Solanum marginatum, Discopodium penninervium* and *Leonotis ocymifolia* are associated shrubs in the community. The common woody climbers of this community are *Rubus steudneri and Clematis simensis.*

4.3.2 *Phytolacca dodecandra - Dombeya torrida* Community type two

This community is located in the altitudinal range between 2456 and 3456 m.a.s.l., and it is represented by 29 woody plant species in 16 quadrats. The dominant plant species in this community is the woody climber *Phytolacca dodecandra* followed by *Dombeya torrida.* Various trees and shrubs including *Juniperus procera, Erythrina brucei, Ficus Sur, Acanthus sennii, Olea europia* subsp. *cuspidata, Buddleja polystachya, Discopodium penninervium,* and *Hagenia abyssinica* make up this community. The woody climbers commonly found in this community were *Mikaniopsis clematoides, Urera hypselodendron, Tacazzea apiculata, Clerodendrum myricoides, Rosa abyssinica* and *Clematis hirsuta. Arundinaria alpina*is the only monocot plant collected from the study area and is found in this community.

4.3.3 *Tamarindus indica - Albizia isenbergiana* Community type three

This community contains the lowest number of quadrats, 4(7.14%) and it is represented by the least numbers of species, only 3(2.70%) compared to the other communities. The altitudinal range of this community is 1406 to 1706 m.a.s.l. *Tamarindus indica* is the most dominant species of this community followed by *Albizia isenbergiana.* The shrub that is represented in this community is *Dichrostachys cinerea.*

4.3.4 *Acacia abyssinica*- ***Croton macrostachyus*** -*Grewia* ***bicolor*** Community type four

This community is found between 1056 and 2806 meters altitude. *Acacia abyssinica* and *Croton macrostachyus* are the dominant trees while *Grewia bicolor* is the dominant shrub in this community. Various trees and shrubs including *Dombeya torrida*, *Tamarindus indica, Ficus glumosa, Anogeissus leiocarpus, Combretum collinum, Dichrostachys cinerea, Grewia ferruginea, Calpurinia aurea, Senna singueana, Justicia schimperiana, Ekebergia capensis, Bersama abyssinica*and *Brucea antidysenterica* make up this community. Woody climbers like *Clematis simensis, Phytolacca dodecandra* and *Urera hypselodendron* are represent this community.

4.5. Species Diversity, Evenness and Richness of the Plant Communities

From the computation of vegetation data obtained from study area, the results of Shannon-Wiener diversity index showed that, community 4 have highest species richness, evenness and diversity (Table 5). This community attained a species evenness index of 0 .95 with average altitude of 1907.8 m a.s.l. Community type 2 showed species evenness index of 0.87 which is the second higher next to community type 4. Community 1 and 3 has low in species evenness index of 0.85 and 0.80 respectively. Community type 1 consists of nine quadrats and the average altitude of this community is 3706 m. a. s. l. Community type 3 is the least community in species richness index of 3 in 4 quadrats.

Table 5: Shannon–Wiener Diversity Index

Community	Average Alt.	Richness	Diversity Index (H')	H'max	Shannon Evenness
1	3706	12	2.12	2.49	0.85
2	3069.3	29	3.01	3.46	0.87
3	1556	3	0.89	1.11	0.80
4	1907.8	81	4.19	4.41	0.95

4.6. Dissimilarities among and within the four plant communities

The Euclidian dissimilarity coefficient was used to determine the dissimilarities within and among plant communities (Tables 6 and 7). The intra and inter cluster (within and among clusters) distances in the four community types were analyzed. Accordingly, community 4 and 2 has greater intra-cluster distance with dissimilarity coefficient of 0.48 and 0.43 respectively. But community 3 has least intra cluster distance (0.21) while that of community 1 has average intra cluster distance of community 2 and 3.

With respect to inter cluster distance of communities, all the four communities have nearly greater inter cluster distance or dissimilarity coefficient. The minimum inter cluster distance coefficient is 0.97 which is found between community 4 and community 3 but the maximum inter cluster distance coefficient is 1 which is found between community 3 and 2 and community 3 and 1.

Generally, community 4 has maximum intra cluster distance while community 3 has minimum intra cluster distance. However, inter cluster distance between community 3 and 2 and 3 and 1 are maximum while inter cluster distance between community 4 and 3 is minimum.

Table 6: Average linkage or Intra-cluster distances between plots

Community 1	Community 2	Community 3	Community 4
0.317935	0.433759	0.210046	0.480299

Table 7:- Average linkage or Inter-cluster distance among communities.

Community	1	2	3	4
1	0.0000	0.987383	1.0000	0.999729
2	0.987383	0.0000	1.0000	0.992415
3	1.0000	1.0000	0.0000	0.970308
4	0.999729	0.992415	0.970308	0.0000

4.7 Density of woody species

The average number of tree and shrub individuals as calculated from the data taken from all plots is 1035.5 per hectare (Figure 12). High density in community one were seen with abundance of 6941 individuals per ha., followed by community three with 1369 individuals per ha. However, community two has least abundance value (820 individuals per ha.) following that of community four (1093 individuals per ha).

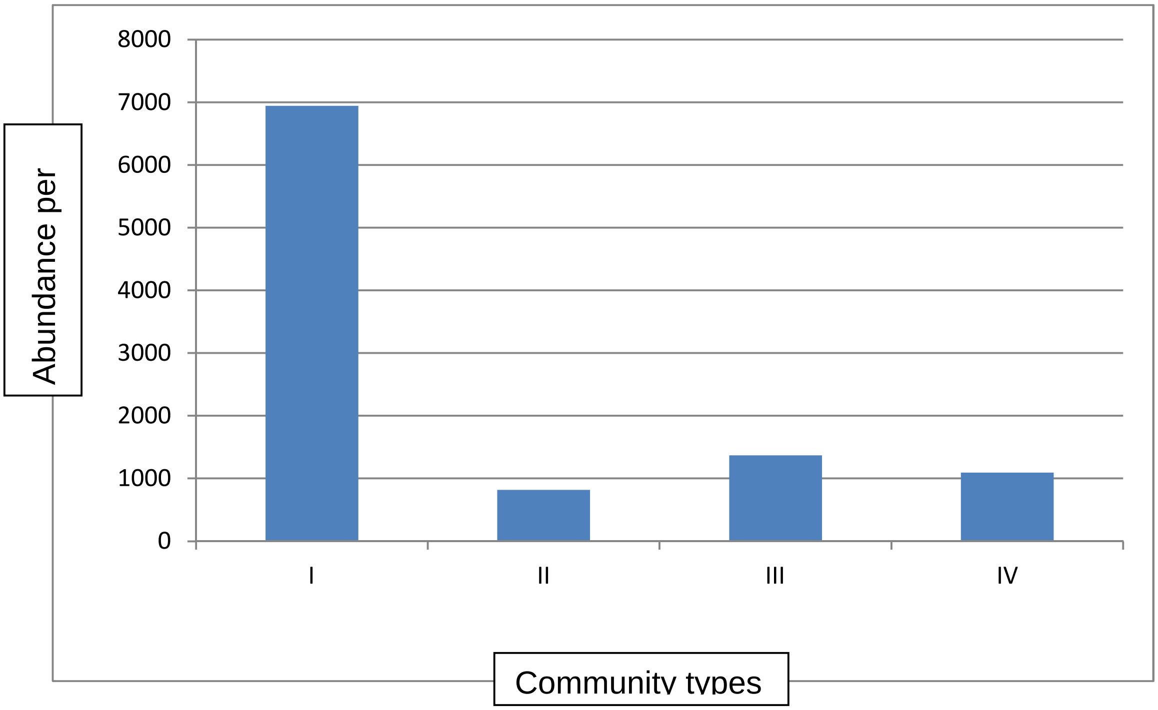


Figure 12: Average Number of individual trees and shrubs of all species per hectare.

4.8 Frequency

Frequency is the number of quadrats in which a given species occurred in the study area. The frequency of all the woody plant species in the study area is given in figure 13. One woody plant species which occurred most frequently (in 12 quadrats out of 56) was *Phytolacca dodecandra*. The second most frequent species were *Acacia abyssinica, Buddleja polystachya, Discopodium penninervium, Dombeya torrid* and *Tamarindus indica* which occurred in 9 quadrats followed by three species (*Brucea antidysenterica, Erica arborea* and *Hypercum quartinianum*) in seven quadrats. The least frequent species in the study area that occurred in a single quadrat were 40 in number followed by 27 species which were occurred in two quadrats.

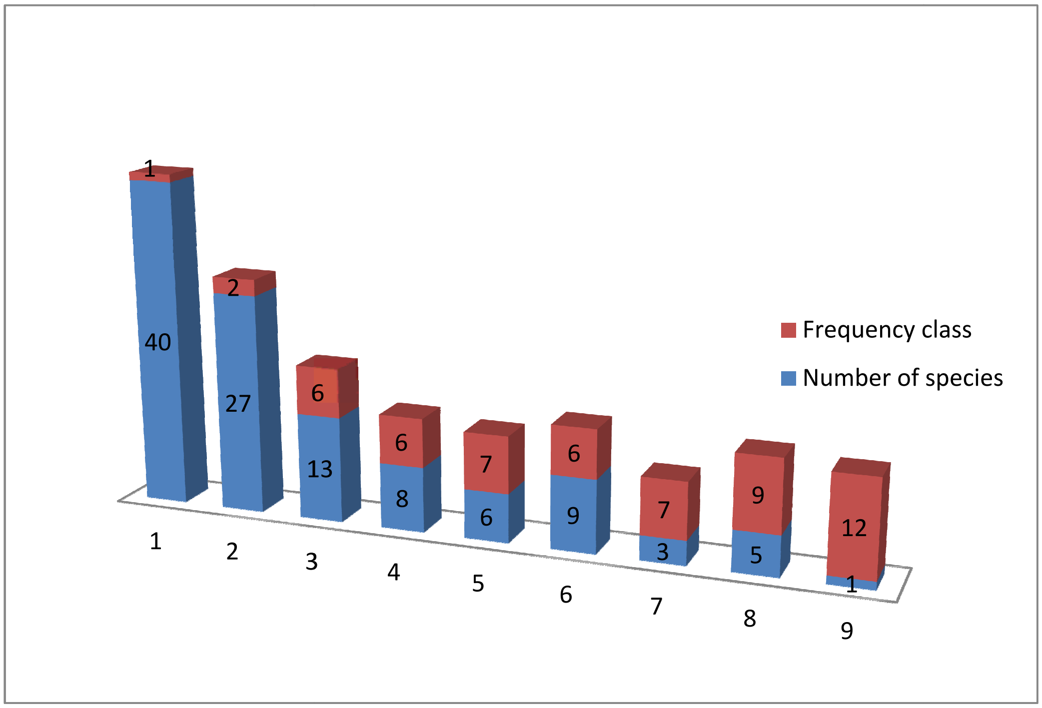


Figure 13: Frequency distribution pattern of woody plant species in Abay Gorge and Choke Mountain.

4.9 Important Value index

The results of important value index (Table 8) showed that *Erica arborea* (24.34%), *Helichrysum citrispinum* (17.50%) and *Europs pinifolius* (16.42%) are the four species with high important value index. *Helichrysum citrispinum*, *Europs pinifolius*and *Erica arborea* are the three species with highest relative density 16.68%, 15.5%, and 14.04% respectively. *Hagenia abyssinica* is the most dominant species followed by *Dombeya torrida* since they have relative dominance value of 11.9% and 9.54% respectively. In terms of relative frequency, *Phytolacca dodecandra* (3.69%) is the most frequent species.

Table 8: Important value indices of 20 most dominant shrubs and trees in the study area with IVI value greater than 5. (R. = Relative).

No.	Species Name	R. frequency	R.density	R.Dominancy	IVI
1	*Erica arborea*	2.46%	**14.04%**	**7.84%**	**24.34%**
2	*Helichrysum citrispinum*	0.92%	**16.58%**	0.00%	**17.50%**
3	*Europs pinifolius*	0.92%	**15.50%**	0.00%	**16.42%**
4	*Hagenia abyssinica*	1.54%	0.52%	**11.94%**	**14.00%**
5	*Dombeya torrida*	2.87	1.45%	**9.54%**	13.86%
6	*Albizia isenbergiana*	1.54%	3.09%	**7.50%**	12.13%
7	*Combretum collinum*	0.62%	2.13%	6.40%	9.15%
8	*Acacia abyssinica*	2.87%	0.39%	6.63%	8.86%
9	*Tamarindus indica*	2.87%	0.80%	5.33%	8.59%
10	*Arundinaria alpina*	0.62%	1.92%	4.68%	7.22%
11	*Juniperus procera*	1.23%	0.29%	5.33%	6.85%
12	*Euphorbia ampliphylla*	0.31%	0.47%	5.75%	6.53%
13	*Erythrina brucei*	1.23%	0.47%	4.74%	6.44%
14	*Hypercum quartinianum*	2.46%	2.57%	1.54%	6.26%
15	*Buddleja polystachya*	2.87	0.80%	2.41%	5.67%
16	*Grewia bicolor*	1.23%	1.53%	2.61%	5.37%
17	*Dichrostachys cinerea*	1.54%	3.48%	0.33%	5.35%
18	*Phytolacca dodecandra*	**3.69%**	1.56%	0.00%	5.26%
19	*Anogeissus leiocarpus*	0.62%	0.83%	3.65%	5.10%
20	*Calpurinia aurea*	0.92%	4.18%	0.00%	5.10%

4.10 The Relationship of the Vegetation of the Study Area to Environmental Factors

4.10.1 Ordination analysis of vegetation data

Canonical correspondence analysis of Ordination of Vegetation and soil environmental data set are shown in figure 14. The length and direction of an arrow representing a given environmental variable (soil pH and altitude) provided an indication of the importance and direction of the gradient of environmental change for that variable, within the set of samples measured. This CCA test showed that, both environmental variables have equal effect on species distribution, because the two arrows have nearly equal length with each other and the test shows significance value of 0.001. However, both variables are correlated negatively. All the 56 quadrat scores were plotted along the axes and distributed above and below the axes.

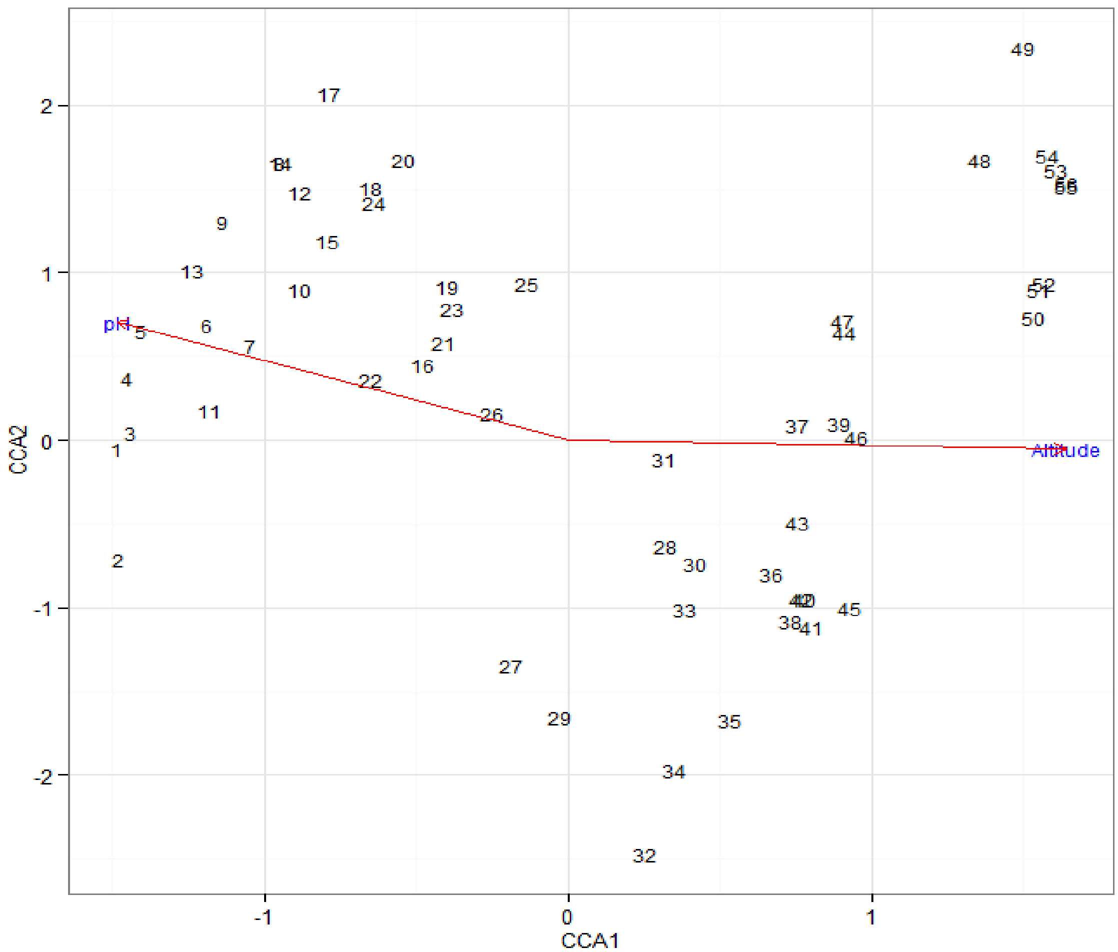


Figure 14**:** Species ordination diagram based on Canonical Correspondence Analysis, with two variables in Abay Gorge and Choke Mountain.

4.10. 2 Impact of Altitude on Vegetation Distribution

The impact of altitude on woody vegetation distribution was assessed by fuzzy set of ordination (Figure 15). Actual elevations and apparent elevations were taken as axes (X, Y axes) and vegetation distribution in this elevation was correlated. The result indicates that the quadrats sampled and the species in the quadrats have strong affinity to elevation (with a correlation coefficient of 0.93), Fig. 15.

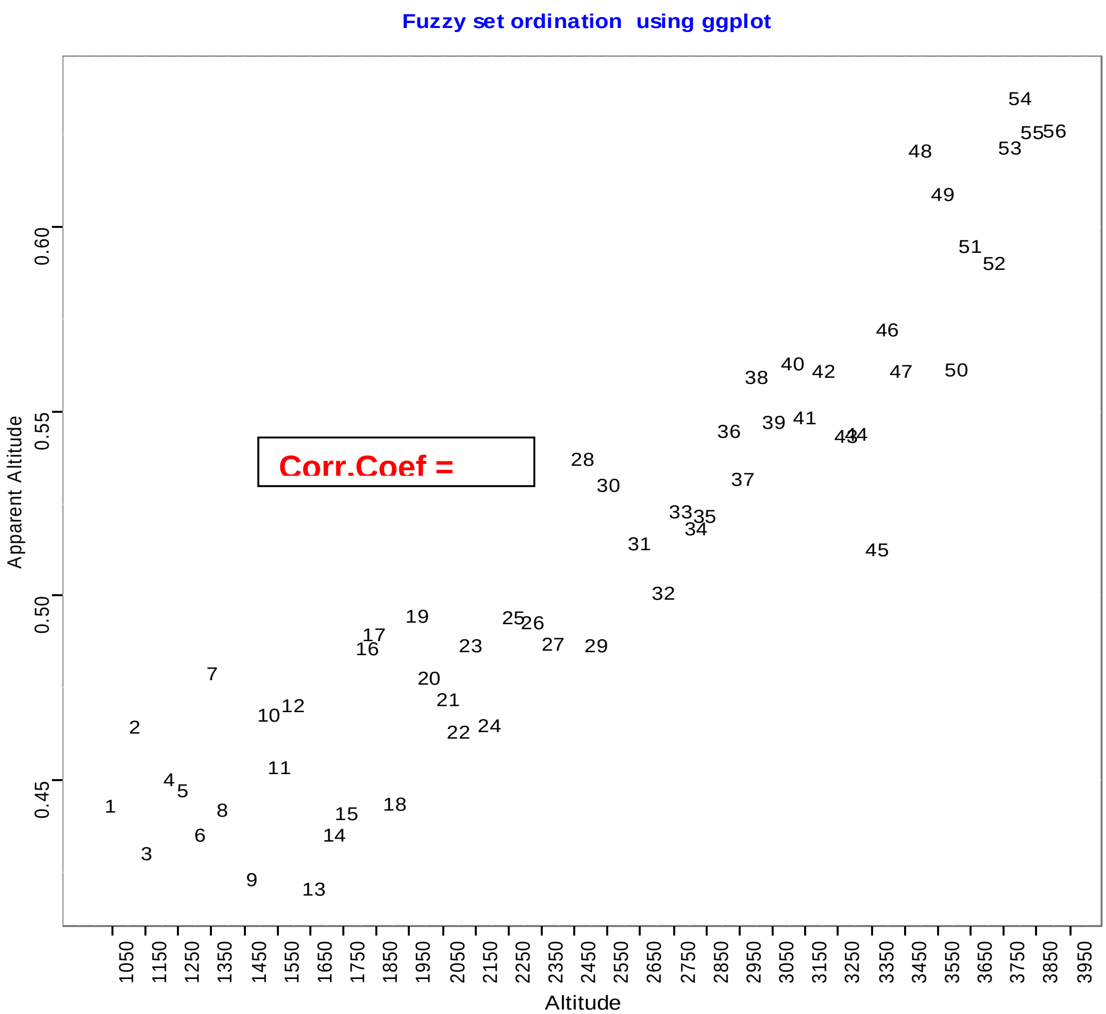


Figure 15: Correlating altitude and Vegetation Distribution in (X, Y) axes. (X axes = actual elevation and Y axes = apparent elevation).

4.10.3 Impact of Soil pH on Vegetation Distribution

The impact of soil pH in woody plant distribution was assessed by fuzzy set of ordination (Figure 16). Unlike altitude, the affinity of the sample plots (quadrats) and soil pH is not as strong as that shown by altitude. This is shown by the non linear distribution of the quadrats along the pH Gradient.

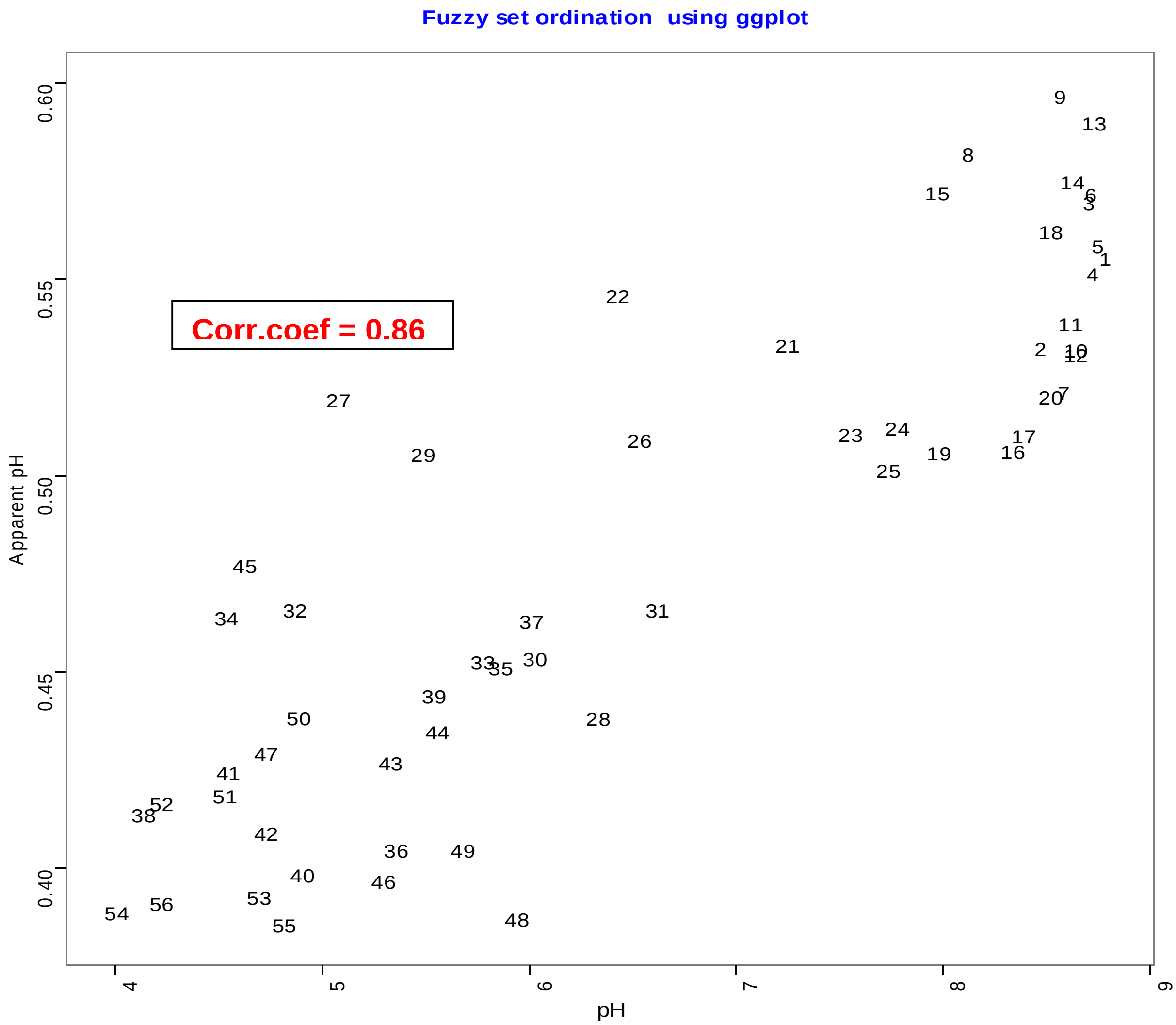


Figure 16**:** Correlating pH and Vegetation Distribution (X axes = actual pH and Y axes = apparent pH).

CHAPTER FIVE

5. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1. Discussion

5.1.1. Floristic Description and Vegetation classification

The top three largest families in the Flora of Ethiopia and Eritrea are Poaceae, Fabaceae and Asteraceae (Ensermu Kelbessa and Sebsebe Demissew, Pers. comm.). Different studies reported dominance of Fabaceae and Asteraceae in Afromontane vegetation type (Dereje Mekonnen 2006; Getachew Tena *et al*., 2008; Motuma Didita *et al.*, 2010; Tamene Yohannes*et al.*, 2013). The dominance of Fabaceae and Asteraceae could be attributed to their efficient and successful dispersal mechanisms and adaptation to a wide range of ecological conditions (Ensermu Kelbessa and Teshome Soromessa, 2008). Similarly, Fabaceae and Asteraceae are the two dominant families in Abay Gorge and Choke Mountain. However, Poaceae was not recorded as a dominant family (only represented by a single woody species, Table 2). The expected reason behind reduction of number of Poaceae is due to the fact that this study focused only on woody species and most grasses are herbaceous.

The dominance of plant families varies from one vegetation type to another in Ethiopia due to variation in topography, ecology, environment and climate. For example, Kumelachew Yeshitela and Tamrat Bekele (2002) reported the dominance of the families Euphorbiaceae and Moraceae from the Afromontane and Transitional Rainforest vegetation types in southwestern Ethiopia, while Getaneh Belachew (2006), reported the dominance of Poaceae from Beschillo and Abay (Blue Nile) Riverine Vegetation type in North East Ethiopia.

Among the total woody plant species, shrubs primarily dominated the growth form comprising 58.04% of the total number of species (Figure 10), followed by trees species comprising 30.63% of the total species, followed by woody climbers/lianas and tree/shrubs comprising 9.01% and 3.6% respectively. Generally, vegetation of the area consists of short-stemmed and multi-branched shrubs of 3 – 4m tall with occasional tackiest and scattered umbrella shaped trees reaching medium height. Shrubs mostly dominated high and low altitudes and trees mostly dominated medium altitudes but both of them are not restricted to the indicated areas only.

Out of 120 threatened endemic plant species listed from Ethiopia, 35 species were from dry Afromontane forests (Ensermu Kelbessa*et al*., 1992). This shows that endemcity is high in the Dry Afromontane forest. According to Kruckeberg and Rabinowitz (1985), this may be due to the fact that endemism may arise due to geographical and ecological isolations of species from the rest. In the present study, out of the 120 identified woody plant species, 13 (10.83%) are endemic to Ethiopia. Out of these (13 identified endemic woody plant species), fourare new records for the floristic region (Gojjam).These are *Inula confertiflora, Mikaniopsis clematoides, Senecio myriocephalus* and *Leucas abyssinica. These four species were not recorded on the flora region in the books of* Flora of Ethiopia and Eritrea (Edwards, S. *et al.,* 2000, Mesfin Tadesse, 2004 and Hedberg, I., *et al.,* 2006). Compared to other studies; for example, Getachew Tena*et al*., (2008) reported only three endemic plants from 174 identified plant species from woody vegetation of Eastern escarpment of Welo, Ethiopia; Mamo Kebede*et al*., (2013) reported only seven endemic woody plant species from moist Afromontane forest of Wondo Genet, South Central Ethiopia.

5.1.2 Diversity of the community types

Community type 1 (*Erica arborea - Hypercum quartinianum* Community) was the third community in species richness, evenness and diversity (Table 5). This community is found in areas with higher altitudes or mountainous areas compared to the rest of the communities.

According to Körner (1998), the major decline in species richness in mountainous areas in higher elevations is due to eco-physiological constrains, such as reduced growing season, low temperature and low ecosystem productivity. In addition, the boundary effect may also have an influence on the species richness at high elevations (Gerytnes and Vetaas, 2002). According to Colwell and Lees (2000), boundary effect is defined in relation to the degree of species resistance to dispersals and survival. Mountains can be represented as islands through their reduced connectivity for colonization by plants. As elevation increases, the isolation of slopes from pathways of migration increases linearly. With reduction of channel available for immigration, reduction in the number of species that occupy high elevation site is great.

Moreover, mountains generally have conical shape and as the elevation increases, the area of the elevation band with certain set of environmental and climatic conditions decreases. With reduced area, there will be fewer micro sites for plants to occupy through the development of specific adaptive traits, due to this reason their species richness and also their abundance is reduced (Yu Hua 2010). This may be one of the cases for the reduction of diversity in Choke Mountain.

Additionally, the low species richness and evenness in community one may be due to the high-level of disturbance factors. Similarly, Belay Simane *et al*. (2012) reported that at present, ecological pressure due to grazing and fuel wood collection is reducing the proportion of the vegetation in Choke Mountain. Lower evenness indicates the dominance of few species in the area (Feyera Senbeta, 2006). Accordingly, few species like *Erica arborea, Hypercum quartinianum, Europs pinifolius* and *Helichrysum citrispinum* were highly dominant in this community.

Community type 2(*Phytolacca dodecandra - Dombeya torrida*community)located between altitudinal ranges of 2456 - 3456 m.a.s.l. This community is characterized by large sized trees with good canopy and woody climbers. The second highest species richness and evenness were obtained in this community. The characteristic woody plants in this community include *Juniperus procera*, *Erythrina brucei*, *Olea europia* subsp. c*uspidata*, *Clausena anisata*, *Buddleja polystachya*.

This community however, is highly susceptible to agricultural activities, plantation of exotic plants like *Eucalyptus globules* and intensive grazing. Due to the reduction of the natural dominant plant species in the area, *Eucalyptus globules*is extensively cultivated in plantations, and some of the residents in the area have become dependent on it for their livelihood (Belay Simane *et al*., 2013).

Community 3 (*Tamarindus indica - Albizia isenbergiana* Community) was distributed in the altitudinal renege of 1406 to 1706 m.a.s.l. This community is least in every aspect like species richness, evenness, diversity and it is also located in lower altitude.

Moreover, this community is found at the lower path of the study area near the Abay Gorge. The area is known by high soil pH, low precipitation, irregular topography, rocky slopes and has high average annual temperature (Figures 2&3). The sum totals of this favored the reduction in species richness, evenness and diversity in this community.

Community 4 (*Acacia abyssinica* - *Croton macrostachyus* -*Grewia bicolor* Community) is found between 1056 and 2806 m. altitude and is dominated by *Acacia abyssinica*, *Croton macrostachyus* and*Grewia bicolor*. Woody climbers like *Clematis simensis, Phytolacca dodecandra* and *Urera hypselodendron* also occur in this community. Furthermore, this community contains four sub-communities with distinct vegetation variations. Subcommunity 1 and 3 include species in remnant vegetations in farmland and rocky slopes in Abay Gorge, sub-community 2 shrubs and shrubby-trees around Abay River and sub-community 4 contains species of farmland with relatively flat topography.

Generally, community type four has higher species richness, diversity and evenness when compared to communities one, two and three (Table 5). The core contributor for this high value is the occurrence of the community in high altitudinal range, in a natural forest patch and in preserved natural vegetation around Abay Gorge. The other expected reason for the existence of high diversity and richness is manmade protection and inaccessible hill-slops in Abay Gorge. According to Getachew Tena *et al.* (2008), species diversity and richness can be attributed to manmade protection and inaccessible hill-slops.

High intra-community or intra-cluster dissimilarity coefficient were exhibited in community 1 and 3 which is 0.21 and 0.31 respectively, while least intra-cluster similarity were seen in community 2 and 4 which is 0.43 and 0.48 respectively (Table 6).

On the other hand, inter-community or inter-cluster dissimilarity coefficient showed that community one is completely dissimilar with community three, while community two is completely dissimilar with that of community three with dissimilarity coefficient of one, but community one and two; one and four; two and four and three and four have nearly equal similarity coefficients. Relatively, larger inter-community or inter-cluster similarity was seen in community four and three.

Generally, low intra-cluster distance indicates that, species that are found within a single community are different from each other in every quadrats or number of common species in each quadrat is low in one community. In inter-cluster dissimilarity there is no common species between community one and three and in community two and three, but community four and three have relatively high number of species in common than others. Community one is located in mountain range with high grazing and anthropogenic effect, community two and three is located in farmland but at completely varied altitudinal range. However, community four is located partly in farmland and partly in preserved lowland. All anthropogenic and other factors like altitude and environment contributed for high intra and inter cluster dissimilarities.

5.1.3 Density of woody species

The average number of trees and shrubs in this study is 1035.5 per hectare (Figure 7). The mean density of woody species of the study vegetation was three times less than that of woody vegetation in Eastern escarpment of Wello (3146 per ha) and that of woody vegetation in Borana lowlands (3149 per ha) (Getachew Tena*et al.*, 2008, Gemedo Dalle, 2004) respectively. High density in community one is either due to natural or manmade protection of *Erica arborea* in afro alpine areas or it is due to the small size of *Europs pinifolius* and *Helichrysum citrispinum* that contribute higher total count within a given quadrat. Contrary to this lower density in community two, three and four may be due to high grazing and browsing pressures, cutting of shrubs and trees for firewood, Charcoal production and house construction.

5.1.4 Frequency

Frequency is the number of quadrats in which a given species occurred in the study area. Frequency classes of woody plant species of Abay Gorge and Choke Mountain were shown in figure 8. According to Tamene Yohannes *et al.* (2013), frequency indicates an approximate floristic homogeneity and heterogeneity. High value in higher frequency classes and low value in lower frequency classes indicates constant or similar species composition. On the other hand, high value in lower frequency classes and low values in higher frequency classes indicate high degree of floristic heterogeneity. Similarly, the result of this study showed that, there are high values in lower frequency classes and low values in higher frequency classes, which indicates the high floristic heterogeneity of Abay Gorge and Choke Mountain.

5.1.5 Important Value Index

Important Value Index is used to determine the overall importance of each species in the area and it helps to combine data for three parameters (relative frequency, relative density and relative abundance).It is for this reason, ecologists consider IVI as the most important topic in vegetation study (Curtis and Mcintosh, 1951). In this study, six species scored IVI greater than ten (Table 8). The most ecologically important woody species, *Erica arborea* was almost twice more important than the fifth ranked species, *Albizia isenbergiana* andnearly twice that of third and fourth ranked species. The IVI class distribution showed that 44% of the woody species have an IVI between 0.1–1.0; 39% of the woody species have an IVI between 1.1- 5.00; 12%of the woody species have an IVI between 5.1–10.0 and 5% of the woody species have an IVI greater than 10. It is a good index for summarizing vegetation characteristics, ranking species and conservation practices (Kent and Coker 1992). In other words, it reflects the degree of dominance and abundance of a given species in relation to the other species in the area.

5.1.6 Environmental Correlation Analysis

Environmental factors such as altitude, soil pH and climate affects species diversity and richness. Altitudinal differences affect species composition and distribution in plant communities (Figures15&16). At relatively low temperature, high rainfall distribution and in low soil pH, some small sized high acidity tolerant woody plant species like *Europs pinifolius* and *Helichrysum citrispinum* and *Erica arborea* were dominant. According to Sims (1986), soil pH is considered to be the major determinant of vegetation diversity in many habitats. Since the degradation of soil organic matter is microbially mediated, the temperature at which this process occurs is likely to control the content of soil organic matter. The Microbial activities are very slow at higher altitudes (because annual mean temperature is low (Figures 2 &3)) where mineralization processes are reduced.

In contrast, in the lower altitudinal ranges due to high alkalinity, relatively high temperature and low rainfall, some alkalinity tolerant plants like species of *Acacia*and *Tamarindus indica*were dominant. The middle altitudinal and neutral pH ranged areas were represented by few quadrats (the affinity of quadrats towards middle altitudinal and neutral pH ranged areas are low).

The results of the correlation coefficients for vegetation vs. altitude and vegetation vs. soil pH were 0.93 and 0.86 respectively. This clearly shows that altitude and soil pH have great impact in vegetation distribution in the study area. This is in line with Jin *et al.,* (2008) assertion that elevation is the main controlling factor in the vegetation growth.

5.2. Conclusion

Afro-alpine and sub-afroalpine, Dry Evergreen Montane Forest and *Combretum-Terminalia* Woodland vegetation types are represented in this study area. The study area is rich in plant species composition, diversity and endemic woody plant species.

From the study of woody vegetation distribution in this diversified area (Abay Gorge and Choke Mountain), 120 species of woody plants belonging to 90 genera and 48 families were identified and recorded. Fabaceae and Asteraceae were found to be the most dominant families. Shrubs were dominant life forms and trees were the second in dominance followed by woody climbers. Moreover, out of 120 species 13 woody plant species were endemic to Ethiopia.

Vegetation of the area (Abay Gorge and Choke Mountain) is grouped into four community types. The highest species richness and maximum diversity was observed in community four. Community type three exhibited the least species richness and diversity. The variation in species composition and diversity among communities could be associated with different factors, such as altitude, soil pH, climate and anthropogenic impacts. Inter-cluster and intra-cluster distances or distance between communities and distance within a single community is high in this study area.

Average density of woody plant species per hectare is about 1035.5. Maximum density was seen in community one while minimum density was seen in community two. This high density in community one is attributed due to small sized shrubs and preserved forest in the area like *Erica arborea, Europs pinifolius* and *Helichrysum citrispinum.*

Out of 112 woody plant species, only 6 species have IVI value greater than 10. *Erica arborea* has highest IVI value, *Helichrysum citrispinum*has highest density, *Phytolacca dodecandra* has highest frequency and *Hagenia abyssinica* has highest dominance value in the study area.

Altitude and soil pH have strong correlation with types and diversities of plant communities and have great impact on woody vegetation distribution. In addition to these, other environmental factors such as, climate and soil; anthropogenic factors such as agricultural expansion, grazing and browsing by domestic animals, deforestation, illegal charcoal production, fire wood collection and conversion of farm land to eucalypts plantation are the major threats to the woody species in the area.

5.3 Recommendations

- ❖ Abay Gorge and Choke mountain range harbor a number of endemic woody plant species. These areas need to be protected with a full participation of the communities.
- ❖ There is a high risk of food security due to low productivity of the farm. Thus the farmers are growing the eucalypt plantation by converting their farm. This is a worrying trend. Thus, it is here recommended to restrict the expansion of eucalypts farm lands.
- ❖ The soil in the upper altitude is highly acidic while in the lower altitude highly basic which impact vegetation distribution and land productivity. Additional studies are needed to reduce the high acidity and alkalinity of the soil.

- Agricultural activities extend to 3800 m. a. s. l. in some parts of the Choke Mountain. This uncontrolled agricultural activities and overgrazing are threats that are showing their effects on the biodiversity of the mountain. So that, the area needs appropriate management strategy to sustain the biodiversity of the area.
- *Hagenia abyssinica*, *Dombeya torrida* and *Erythrina brucei* are the prominent species of in community one and two. The species are larger in size compared to other trees in the communities where they are found, but no seedlings or saplings were observed. This is because of the fact the species have edible leaves where grazers easily remove them at their seedling stages. Thus, it is recommended that strong management interventions by the concerned bodies are made to alleviate destructions due to grazing these trees in both communities.

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APPENDICES

Appendix1: Synoptic table for with respective community

Scientific Name	Community			
	C 1	C 2	C3	C4
Helichrysum citrispinum	3.78	0	0	0
Europs pinifolius	2.56	0	0	0
Lobelia rhynchopetalum	1.11	0	0	0
Echinops longisetus	1.44	0	0	0
Rubus steudneri	0.89	0	0	0
Leonotis ocymifolia	0.33	0	0	0
Solanum marginatum	0.33	0	0	0
Erica arborea	**5.89**	0	0	0
Hypercum quartinianum	**4.22**	0	0	0
Hagenia abyssinica	2.56	0.69	0	0
Olea europaea subsp. *cuspidata*	0	1.38	0	0
Mikaniopsis clematoides	0	0.75	0	0
Discopodium penninervium	0.56	1.12	0	0
Rosa abyssinica	0	0.5	0	0
Buddleja polystachya	0	1.62	0	0
Clausena anisata	0	0.19	0	0
Carissa spinaram	0	0.19	0	0
Urera hypselodendron	0	0.50	0	0.37
Clematis hirsuta	0	0.69	0	0
Erythrina brucei	0	1.88	0	0
Lippia adoensis	0	0.19	0	0
Phytolacca dodecandra	0	**2.69**	0	0.11
Senecio myriocephalus	0	0.17	0	0
Vernonia leopoldii	0	0.38	0	0.19
Clerodendrum myricoides	0	0.19	0	0
Ficus sur	0	0.31	0	0
Solanum incanum	0	0.24	0	0.15
Tacazzea apiculata	0	0.12	0	0
Clematis simensis	0.33	0.56	0	0.33
Arundinaria alpina	0	0.69	0	0
Gnidia glauca	0	0.12	0	0
Maytenus arbutifolia	0	0.31	0	0
Acanthus sennii	0	0.5	0	0
Aeschynomene abyssinica	0	0.12	0	0
Solanum benderianum	0	0.12	0	0
Dombeya torrida	0	**2.06**	0	0.67

Solanecio gigas	0	0.12	0	0.07
Juniperus procera	0	1.12	0	0.3
Tamarindus indica	0	0	**5.5**	0.89
Albizia isenbergiana	0	0	**3**	0.81
Dichrostachys cinerea	0	0	0.75	0.89
Cordia africana	0	0	0	0.44
Stylosanthes fruticosa	0	0	0	0.07
Acanthus pubescens	0	0	0	0.15
Albiza schimperiana	0	0	0	0.3
Asparagus africanus	0	0	0	0.04
Echinops pappii	0	0	0	0.11
Helichrysum schimperi	0	0	0	0.11
Crotalaria rosenii	0	0	0	0.11
Inula confertiflora	0	0	0	0.11
Ritchiea albersii	0	0	0	0.19
Croton macrostachyus	0	0	0	**1.33**
Vernonia amygdalina	0	0	0	0.41
Capparis cartilaginea	0	0	0	0.11
Capparis sepiaria	0	0	0	0.07
Barleria eranthemoides	0	0	0	0.11
Acacia abyssinica	0	0	0	**1.37**
Combretum collinum	0	0	0	0.52
Grewia *trichocarpa*	0	0	0	0.37
Sterculia setigera	0	0	0	0.22
Grewia bicolor	0	0	0	**1.04**
Leucas abyssinica	0	0	0	0.19
Grewia tembensis	0	0	0	0.41
Anogeissus leiocarpus	0	0	0	0.71
Conyza pyrrhopappa	0	0	0	0.22
Ficus glumosa	0	0	0	0.67
Grewia ferruginea	0	0	0	0.67
Dodonaea angustifolia	0	0	0	0.19
Osyris quadripartita	0	0	0	0.37
Calpurinia aurea	0	0.31	0	0.56
Cordia crenata	0	0	0	0.22
Maerua pseudopetalosa	0	0	0	0.11
Maesa lanceolata	0	0	0	0.37
Ziziphus mucronata	0	0	0	0.22
Ximenia americana	0	0	0	0.37
Clutia abyssinica	0	0	0	0.33
Senna singueana	0	0	0	0.56

Stereospermum kunthianum	0	0	0	0.22
Maytenus senegalensis	0	0	0	0.48
Myrica salicifolia	0	0	0	0.33
Justicia schimperiana	0	0	0	0.67
Euclea racemosa subsp. *schimperi*	0	0	0	0.44
Cardiospermum halicacabum	0	0	0	0.11
Trichodesma zeylanicum	0	0	0	0.11
Triumfetta flavescens	0	0	0	0.07
Pavetta abyssinica	0	0	0	0.3
Ekebergia capensis	0	0	0	0.96
Crotalaria lachnophora	0	0	0	0.11
Acacia seyal	0	0	0	0.26
Jasminium abyssinicum	0	0	0	0.22
Ficus vasta	0	0	0	0.44
Apodytes dimidiata	0	0	0	0.19
Indigofera schimperi	0	0	0	0.22
Rhus natalensis	0	0	0	0.3
Allophylus abyssinicus	0	0	0	0.3
Bersama abyssinica	0	0	0	0.67
Euphorbia ampliphylla	0	0	0	0.3
Olinia rochetiana	0	0	0	0.19
Pittosporum viridiflorum	0	0	0	0.22
Brucea antidysenterica	0	0	0	0.59
Myrsine africana	0	0	0	0.26
Embelia schimperi	0	0	0	0.19
Prunus africana	0	0	0	0.44
Vernonia francavillana	0	0	0	0.22
Acacia nilotica	0	0	0	0.41
Acalypha fruticosa	0	0	0	0.11
Lagera tomentosa	0	0	0	0.37
Ocimum americanum	0	0	0	0.11
Crotalaria pycnostachya	0	0	0	0.19
Rumex nervosus	0	0	0	0.15

Appendix 2**.** List of plant species collected from Abay Gorge and Choke Mountain.

No.	Scientific Name	Family name	Endemicity	Habit
1	*Acacia abyssinica* Hochst. ex Benth.	Fabaceae		Tree
2	*Acacia nilotica* (L.) Willd. *ex*Del.	Fabaceae		Tree
3	*Acacia seyal* Del.	Fabaceae		Tree
4	*Acalypha fruticosa* Forssk.	Euphorbiaceae		Shrub
5	*Acanthus pubescens* (Oliv.) Engl.	Acanthaceae		Shrub
6*	*Acanthus sennii* Chiov.	Acanthaceae	Endemic	Shrub
7	*Aeschynomene abyssinica* (A. Rich.) Vatke	Fabaceae		Shrub
8	*Albizia isenbergiana* (A. Rich.) Fourn.	Fabaceae		Tree
9	*Albiza schimperiana* Oliv.	Fabaceae		Tree
10	*Allophylus abyssinicus* (Hochst.) Radlk.	Sapindaceae		Tree
11	*Anogeissus leiocarpus* (A. DC.) Guill. & Perr.	Combretaceae		Tree
12	*Apodytes dimidiata* E. Mey. ex Arn.	Icacinaceae		Tree
13	*Arundinaria alpina* K. Schum.	Poaceae		Shrub
14	*Asparagus africanus* Lam.	Asparagaceae		Shrub
15	*Barleria eranthemoides* R. Br.	Acanthaceae		Shrub
16	*Bersama abyssinica* Fresen.	Melianthaceae		Tree
17	*Brucea antidysenterica* J.F. Mill.	Simaroubaceae		shrub
18	*Buddleja polystachya* Fresen.	Loganiaceae		Tree/S
19	*Capparis cartilaginea* Decne .	Capparidaceae		Shrub
20	*Capparis sepiaria* L.	Capparidaceae		Shrub
21	*Calpurinia aurea* (Ait.) Benth.	Fabaceae		Shrub
22	*Cardiospermum halicacabum* L.	Sapindaceae		Climber
23	*Carissa spinaram* L.	Apocynaceae		Shrub
24	*Clausena anisata (Willd.) Benth.*	Rutaceae		Shrub
25	*Clerodendrum myricoides (Hochst.) Vatke*	Lamiaceae		Shrub
26	*Clematis hirsuta Perr. Guill*	Ranunculaceae		Climber
27	*Clematis simensis Fresen.*	Ranunculaceae		Climber

28	*Clutia abyssinica Jaub. & Spach.*	Euphorbiaceae		Shrub
29	Combretum collinum Fres*en.*	Combretaceae		Tree
30	*Conyza pyrrhopappa Sch. Bip. ex A.Rich.*	Asteraceae		Shrub
31	*Cordia africana Lam.*	Boraginaceae		Tree
32	*Cordia crenata Del.*	Boroginaceae		Tree
33	*Crotalaria lachnophora Hochst ex A. Rich*	Fabaceae		Shrub
34	*Crotalaria pycnostachya Benth.*	Fabaceae		Shrub
35	*Crotalaria rosenii (Pax) Milne-Redh. ex Polhill*	Fabaceae		Shrub
36	*Croton macrostachyus Del.*	Euphorbiaceae		Tree
37	*Dichrostachys cinerea (L.) Wight & Arn.*	Fabaceae		Tree
38	*Discopodium penninervium Hochst.*	Solanaceae		Shrub
39	*Dodonaea angustifolia L. f*	Sapindaceae		Shrub
40	*Dombeya torrida (J.F.Gmel.) P. Bamps*	Sterculiaceae		Tree
41*	*Echinops longisetus A. Rich.*	Asteraceae	Endemic	Shrub
42	*Echinops pappii Chiov.*	Asteraceae		Shrub
43	*Ekebergia capensis Sparrm.*	Meliaceae		Tree
44	*Embelia schimperi Vatke*	Myrsinaceae		Shrub
45	*Erica arborea L.*	Ericaceae		Tree
46*	*Erythrina brucei* Schweinf.	Fabaceae	Endemic	Tree
47	*Euclea racemosa* subsp. *schimperi* (A. DC.) White	Ebanaceae		Shrub
48	*Euphorbia ampliphylla* Pax	Euphorbiaceae		Tree
49*	*Europs pinifolius* A. Rich.	Asteraceae	Endemic	Shrub
50	*Gnidia glauca* (Fresen.) Gilg	Thymelaeaceae		Shrub
51	*Grewia bicolor* Juss.	Tiliaceae		Shrub
52	*Grewia ferruginea* Hochst. ex A. Rich.	Tiliaceae		Shrub
53	*Grewia tembensis* Fresen.	Tiliaceae		Shrub
54	*Grewia trichocarpa* Hochst. ex A. Rich.	Tiliaceae		Tree
55	*Ficus glumosa* Del.	Moraceae		Tree

56	*Ficus sur* Forrsk.	Moraceae		Tree
57	*Ficus vasta* Forssk .	Moraceae		Tree
58	*Hagenia abyssinica* (Brace) J.F. Gmel.	Rosaceae		Tree
59	*Helichrysum citrispinum* Del.	Asteraceae		Shrub
60	*Helichrysum schimperi* (Sch. Bip. ex A. Rich.) Moeser	Asteraceae		Shrub
61	*Heliotropium cinerascens* DC. & ex DC.	Boraginaceae		Shrub
62	*Hypercum quartinianum* A. Rich.	Hypericaceae		Tree
63	*Indigofera schimperi* Jaub. & Spach	Fabaceae		Shrub
64*	*Inula confertiflora* A. Rich	Asteraceae	Endemic	Shrub
65	*Jasminium abyssinicum* Hochst. ex DC.	Oleaceae		Climber
66	*Juniperus procera* Hochst. ex Endl.	Cupressaceae		Tree
67	*Justicia schimperiana* (Hochst. ex Nees) T. Anders.	Acanthaceae		Shrub
68*	*Lagera tomentosa* (Sch.Bip.ex A. Rich.) Oliv. & Hiern	Asteraceae	Endemic	Shrub
69	*Leonotis ocymifolia* (Burm. F) Iwarsson	Lamiaceae		Shrub
70*	*Leucas abyssinica (Benth.) Briq.*	Lamiaceae	Endemic	Shrub
71*	*Lippia adoensis* Hochst. ex Walp	Verbenaceae	Endemic	Shrub
72*	*Lobelia rhynchopetalum* Hemsl.	Lobeliaceae	Endemic	Shrub
73	*Maerua pseudopetalosa* (Gilg & Bened.) De Wolf	Capparidaceae		Shrub
74	*Maesa lanceolata Forssk.*	Myrsinaceae		Tree
75*	*Mikaniopsis clematoides* (Sch.Bip. ex A.Rich.) Milne-Redh.	Asteraceae	Endemic	Shrub
76	*Maytenus arbutifolia* (A. Rich.) Wilczek	Celastraceae		Tree
77	*Maytenus obscura (*A.Rich.) Cuf.	Celastraceae		Shrub
78	*Maytenus senegalensis* (Lam.) Exell	Celastraceae		Shrub
79	*Myrica salicifolia* A.Rich.	Myricaceae.		Shrub
80	*Myrsine africana* L.	Myrsinaceae		Shrub
81	*Nuxia congesta R.Br*. ex Fresen.	Loganiaceae		Shrub
82	*Ocimum americanum* L.	Lamiaceae		Shrub
83	*Olea europaea* subsp. *cuspidata* (Wall, ex G.Don) Cif.	Oleaceae		Tree

84	*Olinia rochetiana* A. Juss.	Oliniaceae		Shrub
85	*Osyris quadripartita Decn.*	Santalaceae		Shrub
86	*Pavetta abyssinica* Fresen.	Rubiaceae		Shrub
87	*Phytolacca dodecandra* L'Herit	Phytolaccaceae		Climber
88	*Pittosporum viridiflorum Sims*	Pittosporaceae		Tree
89	*Prunus africana* (Hook.f.) Kalkm.	Rosaceae		Tree
90	*Rhamnus staddo* A. Rich.	Rhamnaceae		Shrub
91	*Rhus glutinosa* subsp. *abyssinica* (Oliv.) M. Gilbert	Anacardiaceae		Shrub
92	*Rhus natalensis* Krauss.	Anacardiaceae		Shrub
93	*Ritchiea albersii* Gilg	*Capparidaceae*		Tree
94	*Rosa abyssinica* Lindley	Rosaceae		Climber
95	*Rubus steudneri* Schweinf.	Rosaceae		Climber
96	*Rumex nervosus* Vahl	Polygonaceae		Shrub
97	*Satureja punctata* (Benth.) Briq.	Lamiaceae		Shrub
98*	*Senecio myriocephalus* Sch.Bip. ex A.Rich.	Asteraceae	Endemic	Shrub
99	*Vernonia adoensis* Sch.Bip. ex Walp	Asteraceae		Shrub
100	*Senna multiglandulosa (*Jacq.) Irwin & Barneby	Fabaceae		Shrub
101	*Senna singueana* (Del.) Lock	Fabaceae		Shrub
102	*Sida schimperiana* Hochst. ex A. Rich.	Malvaceae		Shrub
103*	*Solanecio gigas* (Vatke) C. Jeffrey	Asteraceae	Endemic	Shrub
104	*Solanum anguivi* Lam.	Solanaceae		Shrub
105	*Solanum benderianum* Schimper ex Dammer	Solanaceae		Shrub
106	*Solanum incanum* L.	Solanaceae		Shrub
107	Solanum *marginatum* L. f.	Solanaceae		Shrub
108	*Sterculia setigera* Del.	Sterculiaceae		Tree
109	*Stereospermum kunthianum* Cham.	Bignoniaceae		Tree
110	*Stylosanthes fruticosa* (Retz.) Alston	Fabaceae		Shrub
111	*Tacazzea apiculata* Oliv.	Asclepiadaceae		Climber
112	*Tamarindus indica* L.	Fabaceae		Tree
113	*Trichodesma zeylanicum* (Burm. f.)	Boraginaceae		Shrub

	R. Br.			
114	*Triumfetta flavescens* Hochst.	Tiliaceae		Shrub
115	*Urera hypselodendron* (A. Rich.) Wedd.	*Urticaceae*		Climber
116	*Vernonia amygdalina* Del.	Asteraceae		Tree/S
117	*Vernonia francavillana* Oliv. & Hiern.	Asteraceae		Shrub
118*****	*Vernonia leopoldii* (Sch.Bip.ex Walp.) Vatke	Asteraceae	Endemic	Shrub
119	*Ximenia americana* L.	Olacaceae		Shrub
120	*Ziziphus mucronata*Willd.	Rhamnaceae		Tree/S

* Endemic woody plants of Ethiopia

Appendix 3. Coordinates of the study Area.

Plot (Quadrat)	Altitude	Latitude	Longitude
1	1056	10°08.190'N	038°20.145'E
2	1106	10°08.106'N	038°20.036'E
3	1156	10°08.044'N	038°19.571'E
4	1206	10°08.264'N	038°19.290'E
5	1256	10°08.483'N	038°19.012'E
6	1306	10°09.332'N	038°18.710'E
7	1356	10°09.079'N	038°18.147'E
8	1406	10°09.492'N	038°17.808'E
9	1456	10°09.726'N	038°17.583'E
10	1506	10°10.030'N	038°17.931'E
11	1556	10°10.365'N	038°16.943'E
12	1606	10°10.486'N	038°16.592'E
13	1656	10°10.544'N	038°16.403'E
14	1706	10°10.616'N	038°16.088'E
15	1756	10°10.619'N	038°15.849'E
16	1806	10°11.405'N	038°15.915'E
17	1856	10°11.042'N	038°15.087'E
18	1906	10°11.484'N	038°15.073'E
19	1956	10°12.045'N	038°15.330'E
20	2006	10°12.488'N	038°15.766'E
21	2056	10°13.107'N	038°15.907'E
22	2106	10°13.457'N	038°16.533'E
23	2156	10°13.655'N	038°16.452'E
24	2206	10°13.672'N	038°16.348'E
25	2256	10°13.933'N	038°16.664'E
26	2306	10°14.214'N	038°16.843'E
27	2406	10°14.441'N	038°16.630'E
28	2456	10°15.041'N	037°56.340'E
29	2506	10°16.183'N	037°59.213'E
30	2556	10°27.899'N	037°58.478'E
31	2656	10°43.753'N	037°58.871'E
32	2706	10°43.217'N	037°64.164'E
33	2756	10°44.372'N	037°69.839'E
34	2806	10°47.610'N	037°72.621'E
35	2856	10°51.708'N	037°72.871'E
36	2906	10°54.342'N	037°74.213'E
37	2956	10°56.027'N	037°75.414'E
38	3006	10°56.548'N	037°76.327'E

39	3056	10°56.787'N	037°77.049'E
40	3106	10°57.489'N	037°78.007'E
41	3156	10°59.986'N	037°78.370'E
42	3206	10°58.848'N	037°79.420'E
43	3256	10°59.937'N	037°80.093'E
44	3306	10°60.423'N	037°80.847'E
45	3356	10°60.516'N	037°81.291'E
46	3406	10°60.860'N	037°81.553'E
47	3456	10°61.828'N	037°82.467'E
48	3506	10°62.793'N	037°83.382'E
49	3556	10°63.050'N	037°83.405'E
50	3606	10°62.131'N	037°81.391'E
51	3656	10°62.826'N	037°82.440'E
52	3706	10°63.364'N	037°82.687'E
53	3756	10°63.654'N	037°82.806'E
54	3806	10°63.789'N	037°83.113'E
55	3856	10°63.967'N	037°83.266'E
56	3906	10°64.142'N	037°83.593'E

Declaration

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

Zewde Achiso Kerato Signature:________________Date:__________________

This Thesis work has been done under my Supervision

Prof. Zerihun Woldu (PhD.) Signature: ______________Date:_______________

Prof. Sebsebe Demissew (PhD.) Signature:_____________Date:__________________