Ecological Study of Shrubland Vegetation along the Escarpments between Addis Alem and Wolenkomi, West Shewa, Oromoia National Regional State

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This is to certify that the thesis prepared by Abdi shentema, entitled: *Ecological study of Shrub land vegetation along the escarpments between Addis Alem and Wolenkomi*, Oromia National Regional State in partial fulfillment of the requirements for the Degree of Master of Science (Plant Biology and biodiversity Management: Plant Ecology) complies with regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Ecological Study of Shrubland Vegetation along the Escarpments between Addis Alem and Wolenkomi, West Shewa, Oromoia National Regional State

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The study was conducted in Oromia National Regional State, West Shewa Zone, along escarpments between Addis Alem and Wolenkomi towns with objective of investigating ecology of shrubland vegetation of the area. Vegetation data were collected from 50 quadrats which were systematically laid. Quaqrats of 20 m x 20 m (400 m^2) were laid for woody species (shrub/trees). For the collection of herbaceous species, subplots of 1 m x 1 m at the four corners and the center of the large quadrat were established. Cover abundance value of all the species was estimated in the field, and then later converted to the Braun-Blanquet 1-9 scale as modified by van der Maarel (1979). One hundred and one plant species were collected and identified there were grouped into 88 genera and 48 families. Hierarchical cluster analysis was employed to analyze community type. Four plant community types: *Euphorbia ampliphylla -Halleria lucida, Dovyalis abyssinica- Ficus sur, Caparris tomentosa - Maesa lanceolata* and *Rubus apetalus - Indigofera spicata* were identified. Shannon - Wiener index of species diversity was applied in order to evaluate species diversity and richness. Accordingly, community type 2 is the highest in diversity (3.7 diversity index) while community type 1 is the lowest in diversity (2.88 diversity index). Height and diameter at breast height (DBH) of all woody species taller than 2 m and thicker than 2 cm were measured in the field. The overall density of tree or shrub species which have DBH >2cm was 874 individual/ha. Based on the computation of Importance Value Index, *Croton macrostachyus, Carissa spinarum, Olea europaea* subsp. *cuspidata, Pterolobium stellatum* and *Acacia abyssinica*, were identified to be the dominant woody species of the area.

Key words/phrases: Addis Alem and Wolenkomi, ecological study, plant community, shrubland vegetation, species richness/diversity

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LIST OF ACRYNOMS

DWARDO	Dendi Woreda Agriculture and Rural Development Office
MoA	Ministry of Agriculture
EEO	Ethiopian Environmental Outlook
EPA	Environmental Protection Authority
EFAP	Ethiopian Forest Action Programme
EWARDO	Ejere Woreda Agriculture and Rural Development Office
FAO	Food and Agricultural Organization
IBC	Institute of Biodiversity Conservation
FPA	Forest Priority Area
CBD	Convention on Biological Diversity
IUCN	International Union for the Conservation of Nature and Natural Resources
GDP	Gross Domestic Product
GPS	Geographical Positioning System
ln	natural logarithm
NT-	Near threatened
LC-	Least concerned
PGRC-	Plant Genetic Resource Center

CHAPTER ONE

INTRODUCTION

Ethiopia is one of the tropical countries with diverse flora and fauna. The country possesses about 6000 plant species, of which about 10% are endemic (Ensermu Kelbessa, personal communication). Endemism is reportedly to be high on the plateau and in the mountains, in the Ogaden region and southern woodland. This makes the country one of the most diverse floristic regions in the world. This diversity results from its topography and diverse climatic conditions which led to the emergence of habitats that are suitable for the evolution and survival of various plant and animal species (Brenan, 1978). The highland plateau of Ethiopia with an altitude of above 2500 m covers 40% of the country (EFAP, 1994; Zerihun Woldu, 1999).

The Afromontane areas of eastern Africa, including the Ethiopian highlands, constitute vivid examples of tropical forest ecosystems that have exceptional species richness, high concentrations of endemic species, and which are under great human land-use pressure. They are, therefore, internationally recognized as the Eastern Afromontane Biodiversity Hotspot (Mittermeier *et al*., 2004; cited in Schmitt *et al*., 2009).

Ecosystems are broadly arranged in a latitudinal pattern, with increasing species richness towards the equator (Mutke and Barthlott, 2005). From Ethiopia to the Cape, mountains contain several centres of endemism for birds, mammals, and plants (Fjeldsa and Lovett; 1997; De Klerk *et al*., 2002). The increasing richness of plants and vertebrates toward the equator is related primarily to climatic factors, such as water availability. However, the diversity of land variations, such as topographic, is also important (Mutke *et al*., 2001).

The vegetation of Ethiopia is complex. The complexity arises from the great variation in altitude employing equally great spatial difference in moisture regime as well as temperature (Zerihun Woldu, 1999). According to several reports on Ethiopian forests covered approximately 40% of the land a century ago but now has shrunken to only 3% (EFAP, 1994; Berry, 2003). The extensive deforestation has also led to the extinction of various biotas resulting in significant biodiversity loss (Zerihun Woldu, 1999; Hadgu, 2008). The forest cover of Ethiopia has been diminishing over times due to an ever increasing demand for uncontrolled farmlands, the increasing livestock population, and an increasing demand for fire wood and charcoal with illegal harvesting of the forest and its products (Feyera Senbeta and Demel Teketay, 2003; Teshome Soromessa *et al.,* 2004). Loss of such forest resources would have great implication for the environment, biological diversity and socio-economic setup of the communities. At the moment, most of the remaining forests of the country are confined to south and south-western parts of the country; however, nowadays the remnant forests in these areas are threatened by human activities (Tamirat Bekele, 1994).

Historical document indicated that Ethiopia had experienced substantial deforestation, soil degradation and an increase in the area of bare land over the years. The need for fuelwood, arable land and grazing areas have been indicated as the the main causes of forest degradation; frequently leading to loss of forest cover and biodiversity, erosion, desertification and reduced water resources (Ensermu Kelbessa and Teshome Soromessa, 2008). The depletion of the natural vegetation in many parts of the country has led to the threat and decline in number and area of distribution of many plant species and surprisingly, 120 threatened endemic plant species are known from Ethiopian natural vegetation (Ensermu Kelbessa *et al*., 1992).The loss of vegetation cover on the central plateau of Ethiopia due to the long history of sedentary agriculture coupled with the ragged terrain has resulted in soil erosion which is 100 times greater than the geological rate (Hurni, 1985).

The Ethiopian highlands provide basic ecosystem services that are of regional and global environmental significance. These highlands account for more than half of the total area of the highlands of Africa and play a significant role in the regional climate. More importantly, from these highlands originate international rivers watering the arid and semi-arid lowlands and the neighboring countries. In terms of genetic resources, the Ethiopian highlands are known to be one of the twelve Vavilov centres of the world (Tewolde Berhan G.E., 1990). The region, however, has been experiencing severe land degradation problems that are emanating from the demands of the growing human and livestock populations. This environmental situation not only undermines the agricultural production capacity but also threatens the ecological sustainability of the region. Decline in agricultural productivity in the highlands has largely been associated with high population density, deforestation and intensive cultivation of steep slopes without effective conservation measures. In the densely populated highlands areas of Ethiopia, intensification of agriculture is reducing fallow periods and increasing the farming intensity on crop land. On the other hand, limited access to knowledge of viable soil management options, lack of capacity to invest in soils especially in fertilizers, and having less ability to bear risk and wait for future payoffs from investment constrained farmers attempt to improve soils. As a result, a major part of agricultural land in Ethiopia suffers from intensive cultivation, steep slopes, poor water control and land management, soil erosion and loss of soil nutrients, and is unlikely to support the growing population (FAO, 2003).

The Ethiopian highlands contribute to more than 50 % of the land area with Afromontane vegetation, of which dry montane forests form the largest part (Tamirat Bekele, 1994). The evergreen scrubland vegetation occurs in the highlands of Ethiopia either as an intact scrub, i.e. in association with the dry evergreen montane forest or usually as secondary growth after deforestation of the dry evergreen montane forest. The Dry Evergreen Montane Forest and Evergreen Scrubland vegetations are the characteristic vegetation types of this ecosystem. Shrubland vegetation of West Shewa may be expanded from lower altitudes and drier sites as forests gradually disappeared (Zerihun Woldu and Backeus, I., 1991). The area between Addis Alem and Wolenkomi which was chosen as the study area with patches of shrub lands is a part of shrubland vegetation of West Shewa.

1.1 Significance of the study

The study area located between Addis Alem and Wolenkomi is part of the Ethiopian Highlands encompassed under Eastern Afromontane Biodiversity Hot Spot which is rich in diversity. The existence of this area in Eastern Afromontane biodiversity hot spot and close to the equator enables the area having diverse plant species. However, anthropogenic activities which resulted from increasing human population imposed severe threat to the environment and floristic composition of the area. There are a number of reasons why the residents of the area remove vegetation. These are agricultural land expansion, grazing, fuel wood and charcoal, timber exploitation etc. Therefore, detailed ecological study is desirable to draw the attention of policy makers or government bodies and local communities to understand the ecosystem services of plant biodiversity and undertake appropriate conservation measurements. The study on ecological and floristic composition is vital to call for immediate and timely scientific interventions, to fill information gap and create awareness in the community to uphold the conservation and sustainable use of natural vegetation. This study may contribute to the basic data on ecological, floristic composition and population structure of plants to provide base line information on future ecological and botanical studies of the area.

1.2 Objectives

1.2.1 General Objective

- To investigate the ecology of shrubland vegetation along escarpments between "Addis Alem" and "Wolenkomi".

1.2.2 Specific Objectives

- To study and document the floristic composition of shrubland vegetation between "Addis Alem" and "Wolenkomi",
- To determine plant community types of shrubland vegetation of the study site in terms of species richness, evenness and species diversity,
- To analyze the species population-structure and regeneration status of the woody plant species of the study area and
- To recommend solutions for better conservation and management that tends to ensure the future existence of shrubland vegetation in the study site.

CHAPTER TWO

LITERATURE REVIEW

2.1 Vegetation of Ethiopia

Vegetation may be defined as an assemblage of plants growing together in a particular location and may be characterized either by its component species or by the combination of structural and functional characters that characterize the appearance, or physiognomy, of vegetation (Goldsmith *et al*., 1986). Vegetation formation is influenced by a combination of many factors, such as climate, geology, edaphic factors and biotic factors, including interference by humans in ecological succession. Vegetation is dynamic, that is, constantly changing. Reasons for the changes can be ecological or evolutionary processes, climatic change, human land use, and interaction between factors (Skarpe, 1991).

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

The vegetation of Ethiopia is complex. The complexity arises from the great variation in altitude employing equally great spatial difference in moisture regime as well as temperature (Zerihun Woldu, 1999).Various scholars attempted to classify the vegetation of Ethiopia into different groups. Among scholars who attempted to classify the vegetation of Ethiopia were Ensermu Kelbessa *et al*. (1992), Sebsebe Demisew *et al*. (2004), Sebsebe Demisew *et al.* (1996), Zerihun Woldu (1999), Friis and Sebsebe Demisew (2001), and Sebsebe Demisew and Friis (2009).

According to Zerihun Woldu, 1999), the vegetation of Ethiopia is classified in to 9 types. These are:

1. *Acacia-Commiphora* woodland,

2. Afroalpine and Subafroalpine Vegetation (This zone consists of areas that are, on the average, higher than 3,200 m. These are the slopes and tops of the highest mountains in the country.

3. Combretum – Terminalia (Broad-leaved deciduous) woodland

4. Dry Evergreen Montane Vegetation (This is a very complex vegetation type occurring roughly above 1500 m and below 3200 m in altitude.

5. Lowland Dry Evergreen Forest

6. Moist Evergreen Montane Forest

7. Montane Evergreen Thicket Scrub

8. montane savanna and

9. Semi-desert and Desert Open xerophilous Woodland.

From these one could understand that Ethiopia is a country with diverse vegetation types which in turn gifted the country with a diverse biological prosperity of plants, animals and microbial species. Nevertheless, the attention given to the conservation and sustainable use of these biological resources has been inadequate for many years till now.

2.1.1 Deforestation, Climate Change and Threats to Vegetation in Ethiopia

The historic and ever devastating deforestation in the country has resulted in enormous consequences including chronic shortage of fuel and construction wood, destruction of habitat, loss of biodiversity, soil erosion, desertification intensification and pollution of water resources. There are different factors for the rapid declining of forest cover in Ethiopia and these vary by forest type, location and social and economic circumstances. Rapid human population growth, poverty, forest clearing for cultivation, over-grazing, exploitation of forests for fuelwood and construction materials without replantation are some of the major factors that contribute to the loss of the forest resources. Natural resource degradation, agricultural production, food insecurity, and poverty are all interwoven with each other mutually reinforcing in pushing a down ward spiral (Yonas Yemshaw, 2002). Clearing forests with the aim of opening up a new agriculture land to feed the ever increasing population is the primary cause of deforestation in Ethiopia (Borghesio *et al*., 2004). As the population grows, the availability of land for agriculture shrinks. At the same time, the amount of land to feed the growing population is steadily increasing. With the agricultural productivity increases lagging behind population growth rates, the gap between the availability and the demand for agricultural land continues to grow. This demand for agricultural land is usually culminated in converting more forest into farmland (Friis, 1992; EFAP, 1994). Friis (1992) also described that clearing of forests and woodlands for expansion of permanently cultivated plantation forestry has been very far from meeting the demand for wood for various purposes, such as fuel, construction materials and fodder. In general, the futures of many of the remaining forests of Ethiopia and protected areas were uncertain since the efforts to address the issues and proper guidance and managements even for the selected high Forest Priority Areas (FPAs) are lacking.

According to FAO (1985), the major threats to the conservation of the Ethiopian vegetation are increasingly intensive use of forestlands for agriculture and livestock, need of fuel wood and construction materials, forest fires and human settlement. These major causes of forest destruction are very much interrelated and most are ultimately initiated by the rapid population growth in the country. The underlying causes for these problems emanate from poverty, population growth, lack of alternative livelihoods, inadequate policy support, inappropriate investment and inadequacy of law enforcement. There are 92 high forests in Ethiopia out of which 56 are found in dry evergreen montane forests, 29 in moist evergreen montane forest, 5 in transitional dry moist evergreen montane forests and 2 in lowland semievergreen forests (EFAP, 1994). The moist evergreen forest and the dry evergreen forest are home to a high number of endemic plants and birds and a few of the mammals. However, these forests are still being depleted continuously. The reduction of forests to a few scattered patches, the decline of fauna and difficulty of germination were followed by massive soil erosion and nutrient depletion, resulting in widespread of deficiency diseases of crop plants, animals and reduction of agricultural activities (Legesse Negash, 1995). However, recently forest plantation programs have been initiated on a large scale in selected regional forest priority areas to rehabilitate formerly forested areas and produce industrial and construction wood. They are mainly of exotic tree species with *Eucalyptus* covering the largest area of hardwood plantations. The total area of planted forests is estimated at 216,000 ha and comprises industrial, fuel wood and communal plantations (EEO, 2006; cited in EPA, 2008).

Climatic and ecological changes that influence agricultural activities, economic development and human health are all regulated by biological diversity, particularly the forests. Consequently, the depletion of biodiversity will inevitably hamper sustainable development and endanger humanity's own future (Mugabe, 1998). A changing global climate threatens species and ecosystems. The distribution of species (biogeography) is largely determined by climate, as is the distribution of ecosystems and plant vegetation zones (biomes). Climate change may simply shift these distributions but, for a number of reasons, plants and animals may not be able to adjust. The present century is distinguished from its predecessors in being the first in which the activities of humans have begun to seriously affect the functioning and indeed the viability of our planet as a stable support system for human populations and for the present complement of ecosystems. Evidence of a rapid rise in global concentrations of atmospheric CO_2 is incontrovertible and there is strong evidence that this is causing an enhanced 'green house effect' in which the extra CO_2, together with other pollutant gases (methane, chlorofluorocarbons, nitrous oxide and other trace gases), is acting as an increasingly effective radiation trap and bringing about a progressive rise in global mean temperature. The vegetation covering the land surface of the earth is not immune to these changes and a current task for plant ecologists is to determine to what extent plant populations are already responding to change and to predict the future course of vegetation development (Grime, 1997). Average global temperature has been rising for more than a century, either as a result of natural fluctuation or the build-up of greenhouse gases. Climate change is likely to reduce biodiversity and the goods and services that ecosystems supply in Ethiopia by:

- increasing desertification in arid and semi-arid areas;
- increasing flooding;
- the desiccation and die-back of forests; and
- reduced agricultural production (IBC, 2005)

2.1.2 Dry Evergreen Montane Vegetation of Ethiopia

Dry Evergreen Montane vegetation is a very complex vegetation type occurring roughly above 1500 m and below 3200 m in altitude, with average annual temperature and rainfall of 14-25°C and 700- 1100 mm, respectively (Zerihun Woldu, 1999; Friis, 1992). The bulk of the plateau consists of volcanic rocks. There are, however, Pre- Cambrian outcrops in the south (Sidamo), west (Wellega), north (Tigray) and east (Hararge). The Pre-Cambrian rocks form heterogeneous substrata for plant growth. Some, like the ultrabasics of Wellega, are so deficient in nutrients, especially phosphorus that they tend to be very poor in vegetation cover. Extensive parts of the Tekezze Valley have impoverished vegetation cover because the substratum consists of fossil laterite soils, which are deficient in cations and have been exposed as a result of geological erosion (Zerihun Woldu, 1999).In the extreme north, where the climate is much hotter and drier than further south on the plateau, the lower limit for the dry evergreen montane forest is about 2,100 ma.s.l. The area receives an annual rainfall of 400 mm to 700 mm with an annual temperature between 18°C and 200°C. In the western and central parts (Gojam, Shewa, Wello and Tigray plateaus) the lower altitudinal limit is about 1,900 ma.s.l. with an annual rainfall of 500 - 1,500 mm and annual temperature of 14 -18°C. The upper altitudinal limit in these areas is about 3,200 ma.s.l. In the south and southeastern of the country (Sidamo, Bale and Hararge) this forest type occurs at altitudes between 1,500 and 2,200 ma.s.l. with an annual rainfall of 400-700 mm and temperature between 20 °C and 25 °c. The dominant tree in all cases is *Juniperus procera*, a tree well adapted to dry conditions (PGRC, 1995). About 87% of Dry evergreen montane vegetation zone may have been covered by forests and the remaining 13% by glades of grass lands (Anon, 1981; cited in Zerihun Woldu and Backeus, 1991). The area settled more than 5000BP and widespread deforestation occurred as early as 2500BP (Hurni, 1985; cited in Zerihun Woldu and Backeus, 1991). Dry Evergreen Montane Forest and grassland complex is inhabited by the majority of the Ethiopian population and represents a zone of sedentary cereal-based mixed agriculture for centuries. The forests have diminished due to human interference and replaced by bushlands in most areas. This forest is under severe pressure as a consequence of inhabitants' need for agricultural and grazing land. There is a severe and increasing fuel wood gap in the country, which leads to depletion of standing stock and, hence, further degradation of the remaining forest stands. This is also an ecosystem where livestock density is one of the highest in the country thus exacerbating the degradation process (IBC, 2005). In Dry evergreen montane forest, the canopy is usually dominated by *Podocarpus falcatus, Juniperus procera, Croton macrostachyus and Olea europaea* subsp. *cuspidata*, true lianas, epiphytes including *Peperomia*, ferns and orchids are common. The ground cover is rich in ferns, grasses, sedges and small herbeouceous cotyledons. At the upper limits *Erica arborea, Hagenia abyssinica, Hypericum revolutum, Myrsine africana, Myrsine melanophloeos, Rosa abyssinica,* and *Nuxia congesta* and clumps of *Arundenaria alpina* are also common (Friis, 1992 ;cited in Birhanu Kebede, 2010).

According to Zerihun Woldu (1999), the Dry Evergreen Montane Forest vegetation could be divided into the following five associations:

l. *Mimusops kummel* forests: These are found in western part of northern Ethiopia, e.g. near Lake Tana. The important trees are *Mimusops kummel, Millettia ferruginea, Albizia schimperiana, Celtis africana*.

2. *Podocarpus falcatus* forest: The emergents are individuals of *Podocarpus falcatus*. This type of forest is now rare because *Podocarpus falcatus* has been logged out. But some forests of this type are found in southern Ethiopia, e.g. in the Munessa Forest near Shashemene. Other trees include *Prunus africana, Ekebergia capensis (= E. rueppeliana)*, *Olea* spp., etc. Shrubs include *Calpurnia aurea (= C. subdecandra)* etc. This type of forest occupies the lowest and most humid habitats of the Montane Dry Evergreen Forest.

3. *Juniperus procera* forest: The emergents are individuals of *Juniperus procera*, 30-50m tall. The second stratum is l0-20 m and includes *Ekebergia capensis*, *Millettia ferruginea, Olea europaea* subsp. *cuspidata, Prunus africana, Hagenia abyssinica*, etc. The third and fourth strata include shrubs: *Hypericum revolutum*, *Carissa spinarum, Dodonea angustifolia*, etc. This is the most widespread type of highland forest. It is found in the north, south and east, usually at altitudes of 2200–3200 m, though it can occur as low as l600 m and as high up as 3300 m. It occurs all along the eastern escarpment: in Tigray, especially near Berhale, in Algie and Hugumburda and Grat- Kahsu; in Wollo south of Dessie and Ankober-Debre Sina escarpment including Wuf Washa Forest. Elsewhere this forest type is found in the

Chercher Mountains around Gara-Mullatta and near Asbe Teferi; in the Chilalo Mountains, and in the south in Borana, near Negelle, Yabello and Mega.

4. *Juniperus procera* and *Podocarpus falcatus* forest: The higher and drier habitats are occupied by *Juniperus* forest, and the lower and moister by *Podocarpus*. This type of forest is found mainly in Shewa, Arsi, Bale, Harar and Sidamo.

5. *Acacia abyssinica* forest: This is the driest type, and it is found in the northwest, especially near Lake Tana in Tikur Dengia. The emergents are individuals of *A. abyssinica*. *Acacia abyssinica* is also often found as the dominant tree in montane *Acacia* woodland and groves.

Therefore, according to classification of vegetation types of Ethiopia by Zerihun Woldu (1999), the study site (between Addis Alem and Wolenkomi) could be categorized under dry evergreen montane.

2.2 Shrubland Vegetation

In botany and ecology, shrub is defined as a much-branched woody plant less than 8 m high and usually with many stems. Tall shrubs are mostly 2–8 m high; small shrubs 1–2 m high: subshrubs less than 1 m high. Shrubland is a plant community characterized by vegetation dominated by shrubs, often also including grasses, herbs, and geophytes. Shrubland may either occur naturally or be the result of human activity. It may be the mature vegetation type in a particular region and remain stable over time, or a transitional community that occurs temporarily as the result of a disturbance, such as fire. A stable state may be maintained by regular natural disturbance such as fire or browsing. Shrubs generally greater than 0.5 m tall with individuals or clumps overlapping to not touching (generally forming more than 25% cover, trees generally less than 25% cover). Shrub cover may be less than 25% where it exceeds tree, dwarf-shrub, herb, and nonvascular cover respectively. Vegetation dominated by woody vines is generally treated in this class. Because vegetative growth is limited by thin soils, strong winds, and minimal moisture. The vegetation is dominated by bushy, multiple-stemmed shrubs that are often thorny and have interlocking branches. (http://en.wikipedia.org/wiki/shrubland).

Furthermore, according to EPA (2008), Shrub lands are defined as "a continuous stand of shrubs with a crown density of between 20 -100%. There may be scattered individual trees with a crown cover of less than 20% or scattered clumps (i.e. less than 0.5 hectare) of trees." Dense shrub lands have more than 1,000 stems per hectare, whilst open shrub land has between 999 and 400 shrub stems per hectare. Scattered trees within the shrub layer are classified according to three categories of stem density: densely scattered between 80 and 149 stems per hectare, moderately scatted trees between 40 and 79 stems per hectare, and sparsely scattered less than 39 stems per hectare. The total area of scrublands in Ethiopia is 26.4 million hectares covering 23.1% of the country. The three Regions with the largest area of shrubland are Oromia Region (29%), Somali (20%) and Amhara (16%) (EPA, 2008).

2.3 Plant Community

A plant community is defined as the collection of plant species growing together in particular location that show a definite association or affinity with each other (Kent and Coker 1992). Furthermore, it is a combination of plants that are dependent on their environment, influence one another, and modify their own environment (Mueller - Dombois and Ellenberg, 1974). A community cannot be described simply by listing all the species present, rather it is characterized by detailed studies of those species which most contribute to its unique structure (Kershaw, 1973). Major distinction among plant communities will be made on the bases of physiognomy or the growth form of the vegetation. Plant communities are conceived as types of vegetation recognised by their floristic composition. The species compositions of communities better express their relationships to one another and environment than any other characteristic (Kent and Coker, 1992).

According to Mueller-Dombois and Elenberg (1974) floristic composition of vegetation includes all species occurring within a plant community. However, most plant communities consist of so many different species which are not unique to a given community. Hence, it is common to use the dominant species in naming plant communities (Kent and Coker, 1992). There were two schools of thought regarding structure of communities in the past. These are: Clementesian and Gleasonian views. Clementesian view considers plant communities as discrete units and Gleasonian view regarded plant communities as continuous entities (Lewis and Tayler, 1979). Clementesian School, understands communities as superorganisms that have its own life and structure as well as its own temporal and spatial limits. The temporal component is referred to as the developmental stages of the communities (succession) while the spatial limits are due to the response of species to environmental gradients (Brown and Lomolin, 1998). However, recently Collins *et al*. (1993) have proposed a "hierarchical continuum" concept of the community patterns. This model was based on the assumption that the distribution of species at a regional scale assumes polymodal curve rather than the normal distribution curve of the continuum concept.

2.4 Species Diversity, Species Richness, Evenness and Similarity

Patterns of plant species diversity have often been noted for prioritizing conservation activities because they reflect the underlying ecological processes that are important for management (Lovett *et al*., 2000; cited in Feyera Senbeta, 2006).

The description of plant community involves the analysis of species diversity, evenness and similarity. Diversity and equitability of species in a given plant community are used to interpret the relative variation between and within the community and help to explain the underlying reason for such a difference. The two main factors taken into account when measuring diversity are richness and evenness. Richness is a measure of the number of different species in a given site and can be expressed in a mathematical index to compare diversity between sites (Zerihun Woldu, 1985). Species richness refers to the total number of species in a community whereas evenness is the relative abundance of species within the sample or community making up the richness of an area (Kent and Cooker, 1992). Species richness index is of great importance in assessing taxonomic and ecological values of habitats. A number of indices of diversity have been devised, each of which seeks to express the diversity of a sample or quadrat by a single number. Of the various indices, the most frequently used is the simple totality of species numbers to give species richness (Magurran, 1988). Among many species diversity indices, probably the most widely used to calculate the diversity and evenness includes Shannon-Wiener diversity index, which naturally varies between 1.5 and 3.5 and rarely exceeds 4.5 (Kent and Cooker, 1992). Species diversity could be viewed from different approaches in terms of alpha, beta and gamma diversity (Rosenzweig, 1995). Alpha diversity (α) refers to the diversity of species within a particular habitat or community. The alpha diversity as indicated by Whittaker (1969) is the level of diversity within a habitat or individual community and and is usually expressed by the number of species (i.e., species richness) in that habitat. Beta diversity (β) 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 Cooker, 1992). Gamma diversity (γ) on the other hand is the diversity of species in comparable habitats along geographical gradients and is independent of the two (Kent and Cooker, 1992) or gamma diversity refers to the geographical or landscape diversity (Whittaker et al., 2001). Similarity index measures the degree to which the species composition of the quadrats/ samples is alike, whereas dissimilarity coefficient assesses which two samples/ quadrats differ in composition. It can be used to assess the similarity between different habitats with reference to the composition of species. Jaccard and Sorensen are the most common binary similarity coefficient, because they rely on probability data, except that Sorensen gives more weight to the species that are present in both quadrats and therefore less weight to species that are present in only one quadrat (Kent and Cooker, 1992).

2.5 Biodiversity Conservation and its Significance

All species display genetic variation among individuals and populations. Genetic variation brings natural selection and adaptability to changes in the environment, which ultimately ensures species survival. Genetic diversity in domestic species and their wild relatives enables researchers to develop improved varieties of animals and plants for human needs. Diversity in wild plant species is potentially a major medicinal resource, and it is insurance for further food security. It should also be noted that species that might not have known direct economic value today may turn out to be economically important in the future.

The conservation of biodiversity is fundamental to achieving sustainable development. It provides flexibility and options for our current (and future) use of natural resources.

Almost 85% of the population in Ethiopia lives in rural areas, and a large part of this population depend directly or indirectly on natural resources. Conservation of biodiversity is crucial to the sustainability of sectors as diverse as energy, agriculture, forestry, fisheries, wildlife, industry, health, tourism, commerce, irrigation and power. Ethiopia's development in the future will continue to depend on the foundation provided by living resources and conserving biodiversity (IBC, 2005).

The conservation of species has two main streams: in situ, i.e. .within the confines of communities in their present and, hopefully, their future state of existence; and ex situ, i.e. subject to continuing active support and management by humans outside their existence. Both methods are applied to preserving both wild and domesticated species, a choice, if available, depending on the breeding system, the life cycle, etc., and on the purpose and time scale of preservation. For example, land races of crops are preserved in cultivation which facilitates adaptation to environmental change and in seed storage, for long term security; endangered species are maintained in botanic gardens and in nature reserves and their seeds may be preserved in seed storage (Frankel, 1995).

CHAPTER THREE

MATERIAL AND METHODS

3.1 Description of the study area

3.1.1 Location

The study area is located in Oromia Regional State, West Shewa Zone, encompassing the area between Addis Alem and Wolenkomi town. The study site is found between 50 Km (Addis Alem) and 65 km (Wolenkomi) to the west of Addis Ababa, along the main road from Addis Ababa to Ambo. It lies within 09^{0}01’50.0110N’’ to 09^{0}01’18.0954 N’’ and 038^{0}20’42.647’E to 038^{0}08’54.0677’’E. The area has an altitudinal range of about 2137 to 2289 m a. s. l. The area is situated in part of Ethiopian highlands which is encompassed by one of biodiversity hotspot that includes Ethiopia called Eastern Afromontane biodiversity hotspot which is known by having diverse flora and fauna.

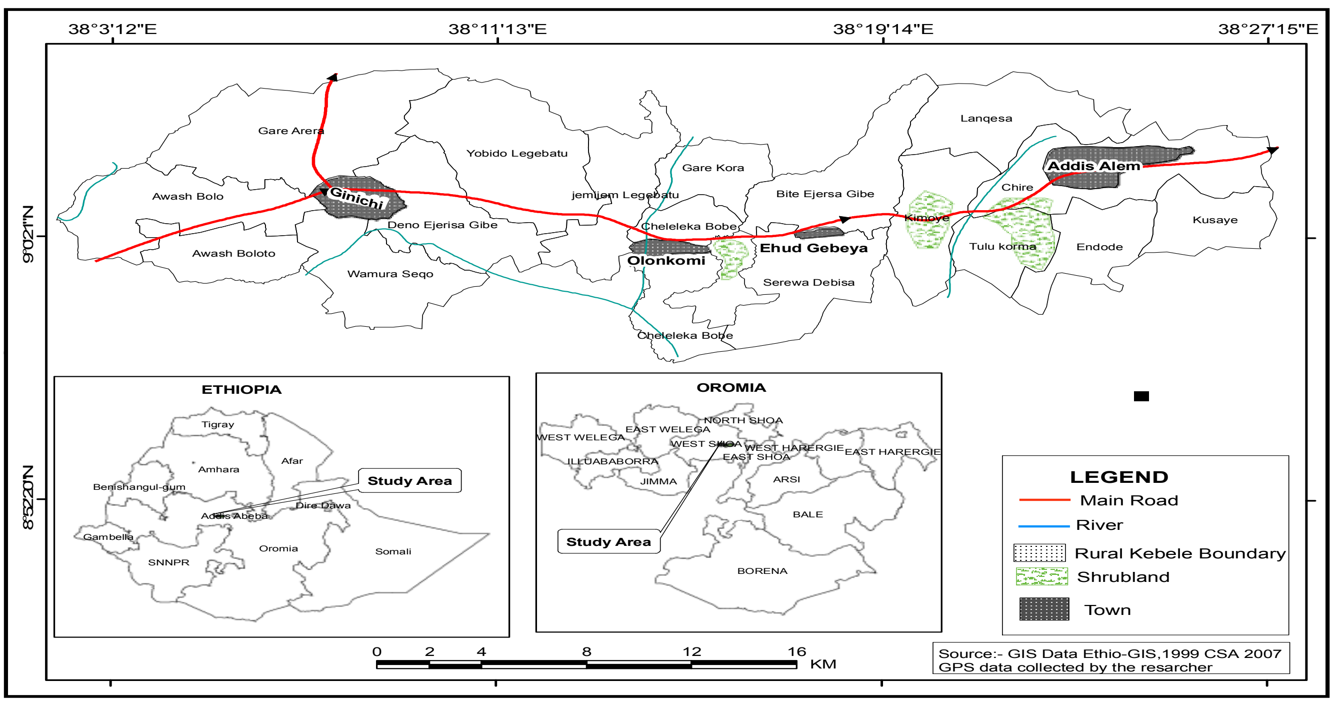


Figure 1 Map of Ethiopia showing the study area

3.1.2 Topography

Topographically, the area between "Addis Alem" and "Wolenkomi" is generally characterized by diverse topographic conditions. These are escarpments, hills, gorges, flat to moderately sloping plateau which is dissected by deep gullies, bordered by river valleys and other land forms. The diversity of terrain of this area contributes to the slight variation of natural vegetation by determining local variations in climate and soil composition which enable the area having diverse floristic composition.

3.1.3 Climate

In order to observe the climatic condition of the study area, the climatic data of Addis Alem were taken.

The data obtained from National Meteorology Service Agency of five years indicates that the mean minimum temperature of Addis Alem is 7^0C which is recorded in the month of November whereas the mean maximum temperature of the area is 26^0C which is recorded in the month of February. The mean annual temperature is about 17^oC.The main rainy months of the area are June, July and August which are approximately estimated to contribute 70% of the annual rainfall whereas the driest months are November, December and January. The mean annual rainfall is about 1140 mm. During the dry season the days are pleasantly warm and the nights are cool. During the rainy season both days and nights are cool.

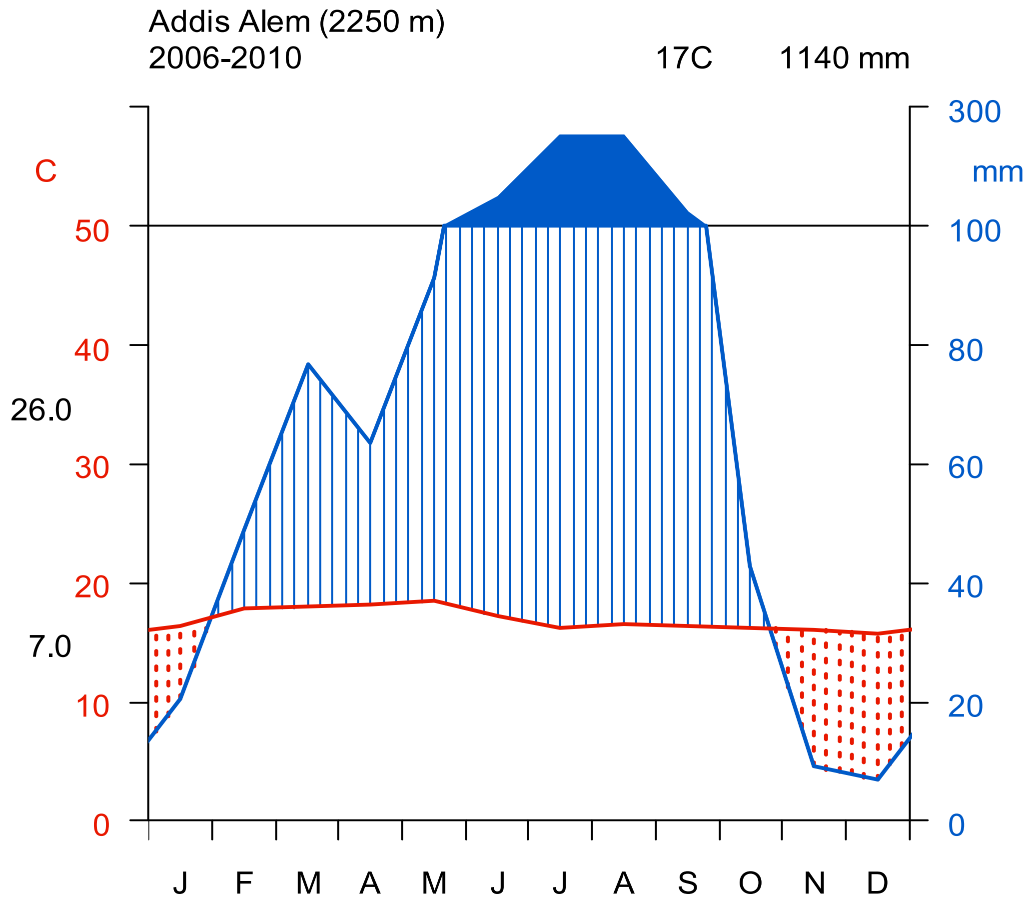


Figure 2 Climadiagram showing rainfall distribution and temperature variation from 2006-2010 at Addis Alem station.

Source: Data obtained from National Meteorological Service Agency(2012)

3.1.4 Human population and Land use pattern

The study area encompasses two districts of West Shewa Zone. Namely, Ejere with the capital Addis Alem and Dendi with the capital Ginchi. According to population and housing census of 2007, the population of Ejere District is estimated to be 89,168 of which males account 45,352 and females account 43, 816 and of Dandi District is estimated to be 170, 233 of which males account 86, 161 and females account 84,072 .The majority of the people reside in rural area and depend on agriculture to sustain their life. As in many other developing countries, agriculture is the mainstay of the Ethiopian economy, accounting for 85 percent of all employment, 40 percent of gross domestic product (GDP), and 90 percent of export earnings (Sinafikish Asrat *et.al*, 2009).

Rapid increase of the number of population from time to time imposed a serious impact on the environment. The study area is densely settled and the land is intensively used. As a result of increasing pressure of population on the land resources of the study area, there has been considerable encroachment of vegetation areas by cultivation. There are many reasons behind for removal of vegetation of the area. The major reasons are agricultural land expansion, fuel wood and charcoal, construction materials, grazing, timber exploitation, road building etc. The consequences of deforestation in the study area are soil erosion, desertification, drought, etc. (personal communication and field observation). The farming system of the area is agro-pastoral. Agricultural production of the area is based on rain fed cultivation and few irrigation activities are also practiced in the area. Major food crops grown by farmers are largely field crops such as TEFF, wheat, barley, chickpea, fababean, NOUG and sorghum are the major crops in the study area. Major livestock reared include cattle, pack animals (mules, horses, and donkeys), sheep and goats and poultry (EWARDO and DWARDO, 2011).

Plate 1.Agricultural land expansion around Kimoye (To the west of Addis Alem)

3.1.5 Vegetation

In reference to the nine vegetation types of Ethiopia discussed by Zerihun Woldu (1999), the study area could be categorized under Dry Evergreen Montane Forest which is characterized by the dominance of *Juniperus* and *Olea* species. However, the distribution of *Juniperus procera* is rare in the study area because of anthropogenic activity. The natural vegetation of the area is dominated by shrubs to the large extent, scattered trees and herbaceous species. The study area is characterized by having diverse plant species such as *Olea europiae* subsp.*cuspidata, Albizia schimperiana, Myrisine africana, Pterolobium stellatum, Carissa spinarum, Maytenus arbutifolia, Juniperus procera, Osyris quadripartita* etc. (see Appendix 2). However, the vegetation of the area is severely threatened today because of anthropogenic activity such as agricultural land expansion and grazing. In addition to this, in many areas, removing of the natural vegetation and replacing it by plantation is common. The other reason for the threat to the vegetation of the area is lack of effective management and policy toward conservation of natural resource (personal communication and field observation).

Plate 2 *Eucalyptus* plantation inside natural vegetation around Addis Alem (Sororo and Negade)

3.1.6 Soil

The physical and chemical compositions of soils are very important in determining the occurrence, growth, diversity and distribution of plant species of the area. Vertisols are the dominant soil class of the study area. According to Misrak Tafesse (2007), the soil around Tulu Korma (Addis Alem) is pellic vertisols, dark in colour which develops from igneous and metamorphic rocks. Cambosols and nitosols are also other soil types of the study area. The volcanic ash, which occurs, for example, extensively over western central Ethiopia (Western Shewa) gives rise to well-drained red soils. These areas were probably well forested before man appeared, but agriculture has been practised for around five thousand years (Zerihun Woldu, 1999).

3.2 Methods

3.2.1 Reconnaissance Survey

A reconnaissance survey was carried out from September 9-11, 2011 in order to obtain an impression of the site condition and to determine the sampling methods to be used for vegetation data collection. The survey focused on identifying the vegetation types and familiarize with the study area, managing bodies of the area and local communities.

3.2.2 Sampling technique

Systematic sampling technique was used to establish the quadrats. Quadrats were laid with 30 m distance between two neighbouring quadrats. Preferential sampling was used in order to choose the study sites where plots were established. Six study sites were selected by considering the amount vegetation each site holds. The sites were namely, Tulu Korma, Sororo and negade, Hontu Aba Garo, Kare Aba Tafa, Gaje (Kimoye) and Wolenkomi.

3.2.3 Vegetation data collection

Vegetation data were collected from October 15 to November 15, 2011. Floristic data were collected from 50 Quaqrats of 20 m x 20 m (400 m^2) that were laid for woody plants. For the collection of herbaceous species, subplots of 1 m x 1 m at the four corners and the center of the large quadrat was established. A complete list of plants was done from each quadrat and percent cover value was visually estimated for each species in the field. The cover abundance for herbaceous species was estimated by calculating the average cover abundance of each herb species existing in five subplots established inside large quadrat. The cover abundance value estimated in the field were later converted to the Braun-Blanquet 1-9 scale as modified by Van der Maarel (1979) as follows

1: Rare, generally one individual;

2: Occasional, with less than 5% cover of the total;

3: Abundant, with less than 5% cover of the total;

4: Very abundant, with less than 5% cover of the total;

5: 5-12% cover of the total area;

6: 12-25% cover of the total area;

7: 25-50% cover of the total area;

8: 50-75% cover of the total area;

9: 75-100% cover of the total area;

All individuals of woody species (shrubs/trees) with a diameter at breast height (DBH) > 2 cm and height > 2 m were measured in the field. DBH of woody plants were measured using meter-tape and heights were estimated visually.

Environmental variables such as altitude and geographic coordinates (latitude and longitude) were taken from the center of each main plot using GPS (Geographical positioning system).

Plant specimens in the field were collected and voucher specimens were pressed and brought to the National Herbarium (ETH) Addis Ababa University for identification. Specimens were identified at the National Herbarium by using published volumes of the Flora of Ethiopia and Eritrea, comparing with authentic specimens already deposited at the National Herbarium and by getting assistance from advisors. The nomenclature of the scientific names of the species and habits follow Flora of Ethiopia and Eritrea Volume 1-7.

3.2.4 Data Analysis

3.2.4.1 Analysis Plant Community type

Classification technique by means of agglomerative hierarchical cluster analysis in R program version 2.11.1 (Venables and Smith, 2010) was employed to analyze the plant community types of shrubland vegetation along escarpments between Addis Alem and Wolenkomi. Classification by means of cluster analysis is the most common multivariate technique to analysis community data and for mapping ecological community (Kershaw, 1973).

For the cluster analysis, abundance data of the 101 species were used. Communities were identified based on groupings of relevés, and four plant community types were produced. "Plant communities whose relevés are considered similar enough are grouped into the same community" (Andreucci et al., 2000).

3.2.4.2 Plant diversity analysis and similarity indices

Shannon-Wiener diversity index is the most popular measure of species diversity because it accounts both for species richness and evenness, and it is not affected by sample size (Kent and Coker, 1992).

Shannon - Wiener (1949) index of species diversity was applied in order to evaluate species diversity of the study area. The two main techniques of measuring diversity are richness and evenness. Richness is a measure of the number of different species in a given site and can be expressed in a mathematical index to compare diversity between sites. Species richness index has a great importance in assessing taxonomic, structural and ecological value of a given habitat. Evenness is a measure of abundance of the different species that make up the richness of the area. Species diversity shows the product of species richness and evenness. (Mueller-Dombis and Ellennberg, 1974).
Shannon-Wiener diversity index is calculated as follows:

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

Where, H' = Shannon diversity index

S = the number of species

Pi = the abundance i^{th} species expressed as proportion of total cover

ln = log $base_n$

ii. Shannon's Eveness (E), is a measure of the relative abundance of the different species making up the richness of an area .It is calculated from the ratio of observed diversity to maximum diversity using the equation

E= H'/ H'max, or

E = H'/ lns, Eveness assumes a value between 0 and 1 with 1 being complete evenness (Kent and Cooker, 1992).The higher the value of evenness index, the more even the species is in their distribution within the given area.

Similarity coefficient - The similarity of vegetation types with regard to species composition was assessed using Sorensen's coefficients as described by Grieg-Smith (1983) and computed from the formula below.

Ss = **2a/ (2a+b+c)**

Where: Ss=Sorensen's similarity coefficient

a= is number of species shared by the two forests/ samples;

b= is the number of species in forest/ sample 1(community1);

c= is the number of species in forest/ sample2 (community2) Kent and Coker (1992)

3.2.4.3 Structural data analysis

Density, frequency, height, diameter at breast height (DBH), species importance value (SIV) and basal area were used for description of vegetation structure. Tree or shrub basal area and density were computed on hectare basis. All individuals of trees and shrub species recorded in all the 50 releves were used in the analysis of vegetation structure. **Importance value index (IVI):** Is used to reflect the extent of the dominance, occurrence and abundance of agiven species in relation to other associated species in an area. It is useful to compare the ecological significance of species (Kent and Coker, 1992).

Importance value indices (IVI) were computed for dominant woody species based on their relative density (RD), relative dominance (RDO) and relative frequency (RF).

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

Therefore, for setting priority, it is a good index for summarizing vegetation characteristics and ranking species for management and conservation practices. Whereas species with lower SIV need high conservation efforts, those with higher SIV need monitoring management (Feyera Abdena, 2010).

Density: is a count of the numbers of individuals of a species within the quadrat (Kent and Coker, 1992). It is closely related to abundance but more useful in estimating the importance of a species. In this study, counting was done in 50 quadrats under study. Afterwards, the sum of individuals per species was calculated in terms of species density per convenient area unit such as a hectare.

$$D = \frac{\text{The number of above ground stems of a species counted}}{\text{Sampled area in hectare}} \times 100$$

Where D=Density

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

Frequency: is defined as the probability or chance of finding a species in a given sample area or quadrat. It is dependent on quadrat size, plant size and patterning in the vegetation (Kent and Coker, 1992). The concept of frequency refers to the uniformity of a species in its distribution over an area. No counting is involved just a record of species present.

It is calculated with this formula:

$$F = \frac{\text{Number of plots in which a species occur}}{\text{Total number of plots}} \times 100$$

Where, F=Frequency

$$R.F = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

Where, RF=Relative frequency

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

$$BA = \pi \ (d / 2)^2 = \frac{\pi d^2}{4}$$ Where,

d is diameter at breast height.

BA=Basal Area in m^2 per hectare

d=diameter at breast height (m)

π=3.14

- RDO= Dominance of a species/Dominance of all species X 100
- Dominance=Mean basal area/tree X the number of tree species

Where, RDO=Relative dominance

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Floristic Composition

A total of 101 species belonging to 88 genera and 48 families were collected and identified, of which 35.64% were shrubs, 34.65% herbs, 22.77% trees, 5.94% climbers and 1% fern species represent the plant species collected from 50 quadrats established in the study area. Out of the species recorded in the study area, angiosperms represent 96%(97 species), gymnosperms 3%(3 species) and fern 1%(1 species).The most dominant families are Fabaceae, comprising 11 species, Asteraceae (ten species), Poaceae (nine species), Lamiacea (six species), Euphorbiaceae (five species) and Acanthaceae (four species). Out 48 families recorded in the study area, about 30 families comprised of only one species each (Appendix 3).

The study area contains 6 out of 24 national priority tree species which are commercially important (EFAP, 1994). The commercially important indigenous species of the area include *Podocarpus falcatus, Ekebergia capensis, Syzygium guineese, Croton macrostachyus, Albizia schimperiana and Juniperus procera.*

4.2 Endemic Species

Out of the plants collected from the study area, seven were endemic species. The endemic species account 6.9% of the total floristic composition of the area, of which shrub represent 42.86%, trees 42.86% and herbs 14.28%. Such plant species are not found elsewhere on the world and need immediate conservation measurement. Therefore, identifying and knowing these species assist us to give conservation priority and effective management. The endemic plant species of the area are listed in Table 1.

Table 1 Endemic plant species collected from the study area. (SU = Shewa, IL = Ilubabor, WG = Wellega, AR = Arsi, KF = Keffa, GG = Gamogofa, SD = Sidamo, GD = Gonder, GJ = Gojam, WU = Welo, BA = Bale, HA = Hararge, TU = Tigray)

Species	Family	Habit	Distribution
Acanthus sennii Chiov	Acanthaceae	Shrub	GD GJ WU SU AR WG KF GG SD BA HA
*Crassocephalum macropappum (*Sch. Bip. ex A. Rich.) S. Moore	Asteraceae	Herb	GD GJ WU SU WG IL KF GG SD BA HA
Erythrina brucei Schweinf.	Fabaceae	Tree	WU, WG, GJ, SU, BA,HA, IL, KF, GD, GG, SD
Millettia ferruginea (Hochst.) Bak subsp. *ferruginea*	Fabaceae	Tree	TU, GD, GJ, SU, WG, IL, HA
Rhus glutinosa A. Rich.subsp.neoglutinosa (Gilbert)Gilbert)	Anacardiaceae	Tree	WU SU AR BA HA
Vepris dainelli (Pichi-serm.) Kokwaro	Rutaceae	Shrub	GJ SU WG IL KF SD BA
Vernonia leopoldii Vatke	Asteraceae	Shrub	TU GD GJ WU SU WG KF HA GG

4.3 Plant community types of the study area

A primary goal of vegetation classification is to arrange vegetation patterns into an ecologically meaningful set of types, with clear diagnostic criteria for identifying the types. Classification also serves to facilitate communication and information-gathering about ecological resources, document the diversity of ecological communities, and provide a framework for addressing scientific inquiries into the patterns of vegetation (Langendoen et al., 2007). Plant community distribution is the manifestation of physical gradients (microclimate, soil heterogeneity and elevation), biotic response to physical gradients and historical disturbances (Urban et al., 2000).

The name for each community type was given based diagnostic species (species occurring only in specific community type). Based on this four community types were identified. The community types of the study area are described below.

*4.3.*1 *Euphorbia ampliphylla -Halleria lucida* Community Type

Euphorbia ampliphylla-Halleria lucida community type is distributed between the altitudinal range of 2160-2248m and comprises 13 plots and 22 species (Appendix 4). *Euphorbia ampliphylla* and *Halleria lucida* are the characteristic shrub species of this community type. The dominant shrubs associated with this community type are: *Carissa spinarum, Euphorbia amphliphylla Pterolobium stellatum*, *Halleria lucida, Premna schimperi*, *Maytenus arbutifolia* and *Myrisine Africana*. The dominant trees of this community type are *Croton macrostachyus* and *Albizia schimperiana* that dominate the upper layer of the community. The dominant herbaceous species in this community type are *Cynodon dactylon*, *Trifolium bilineatum a*nd *Andropogon abyssinicus* dominating the ground flora of the community. The climber *Rhoicissus tridentata is* constituent part of this community type. The other shrub species associated with this community type include *Clausena anisata, Calpurnea aurea and Euclea divinorum.*

Plate 3 *Euphorbia ampliphylla -Halleria lucida* community type

4.3.2. Dovyalis abyssinica- Ficus sur Community Type

This community type is distributed between the altitudinal range of 2196-2283m and comprises 8 plots and 57 species (Appendix 4). The characteristic trees and shrub species of this community type are *Dovyalis abyssinica, Ficus sur, Erythrina brucei, Vepris dainelli, Ficus sycomorus* and *Salix mucronata.* The dominant trees this community type are *Rhus glutinosa, Croton macrostachyus, Eucalyptus globulus, Olea europaea* subsp. *cuspidata and Ficus sur.* The dominant shrubs of this community type are *Premna schimperi, Osyris quadripartita, Pterolobium stellatum*, *Maytenus arbutifolia*, *Dovyalis abyssinica* and *Euclea divinorum*. The important herb species in this community type is *Hyparrhenia hirta* dominating the ground layer of the community. *Clematis hirsuta, Rhoicissus tridentata, Jasminum abyssinicum and Stephania abyssinca* are climbers associated with this community type.

4.3.3 Caparris tomentosa - Maesa lanceolata Community Type

This community type is distributed between the altitudinal range of 2145-2282m and comprises 14 plots and 65 species (Appendix 4). The characteristic trees and shrub species of this community type are *Caparris tomentosa, Maesa lanceolata, Dodonaea angustifolia, Hypericum revolutum, Dovyalis verrucosa, Phytolacca dodecandra and Ocimum lamiifolium.* It is the highest in species richness compared to other community types. Many quadrats included in this community type are relatively far from human encroachment which contributed to high species diversity and richness. The dominant shrubs representing this community type are *Pterolobium stellatum, Carissa spinarum, Caparris tomentosa*, *Myrisine africana and Maytenus arbutifolia.* The dominant trees of this community type are *Olea europaea* subsp. *Cuspidata, Acacia abyssinica and Maesa lanceolata.* The important herbaceous species associated with this community type are *Erythroselinum atropurpureum, Pennisetum villosum and Pennisetum riparium* dominating the lower or ground layer of the community. *Clematis hirsuta, Stephania abyssinca, Jasminum abyssinicum Rhoicissus tridentata and Glycine weghtii* are the constituent climbers of this community type.

Plate 4 Side view of Tulu Korma with *Caparris tomentosa* - *Maesa lanceolata* community type

4.3.4. Rubus apetalus - *Indigofera spicata* Community Type

Rubus apetalus-Indigofera spicata community type is distributed between the altitudinal range of 2137-2289m and comprises 15 plots and 59 species (Appendix 4). The characteristic shrub species of this community are *Rubus apetalus, Indigofera spicata, Rhamnus staddo and Ricinus communis.* The dominant trees in this community type are *Acacia abyssinica, Croton macrostachyus* and *Olea europaea* subsp. *Cuspidata,* dominating the upper layer of the community whereas the dominant shrub species describing this community type are *Carissa spinarum, Pterolobium stellatum, Rubus apetalus and Indigofera spicata.* The dominant herbaceous species of this community type are *Cynodon dactylon, Andropogon abyssinicus, Bidens macroptera and Guizotia schimperi* dominating, the ground layer of the community**.** *Rhoicissus tridentata, Stephania abyssinca, Cucumis ficifolius* and *Clematis hirsuta* are the constituent climbers of this community type.

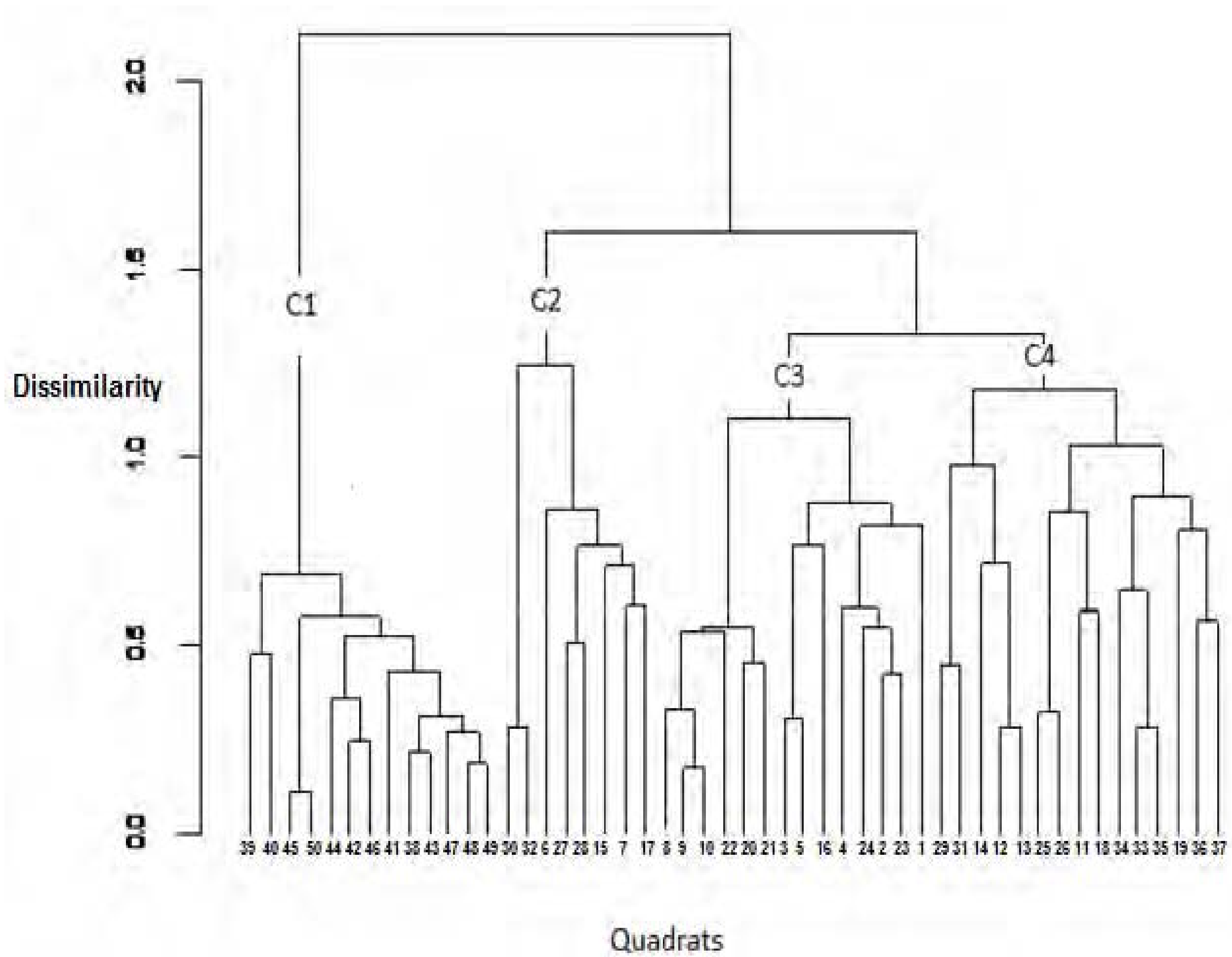


Figure 3 Dendrogram showing plant community types of the study area (X-axis showing the quadrats and Y-axis showing the dissimilarity level).

C1:39, 40,45,50,44,42,46,41,38,43,47,48,49

C2:30, 32, 6,27,2815,7,17

C3:8,9,10,22,20,21,3,5,16,4,24,2,23,1

C4:29,31,14,12,13,25,26,11,18,34,33,35,19,36,37

Table 2 Synoptic Table.

Species	communities			
	1	2	3	4
Acacia abyssinica	*0.00*	*1.50*	*3.21*	*3.93*
Albizia schimperiana	*2.69*	*1.63*	*1.43*	*1.73*
Andropogon abyssinicus	*2.08*	*0.00*	*0.00*	*2.00*
Bidens macroptera	*0.00*	*0.00*	*0.14*	*1.25*
Calpurnea aurea	*1.38*	*0.63*	*2.14*	*1.67*
Caparris tomentosa	*0.00*	*0.00*	***2.56***	*0.00*
Carissa spinarum	*4.00*	*1.38*	*5.79*	*4.47*
Clausena anisata	*2.00*	*2.13*	*1.57*	*1.20*
Clematis hirsuta	*0.00*	*1.25*	*1.29*	*0.13*
Conyza stricta	*0.00*	*0.25*	*0.00*	*0.00*
Crassocephalum vitellinum	*0.00*	*0.00*	*0.29*	*0.00*
Croton macrostachyus	*3.92*	*3.75*	*2.43*	*2.80*
Cynodon dactylon	*2.46*	*0.63*	*1.14*	*2.20*
Cyperus fischerianus	*0.00*	*1.00*	*0.00*	*0.00*
Dodonaea angustifolia	*0.00*	*0.00*	*1.57*	*0.00*
Dovyalis verrucosa	*0.00*	*0.00*	*1.43*	*0.00*
Dovyalis abyssinica	*0.00*	***2.38***	*0.00*	*0.00*
Erythrina brucei	*0.00*	*1.75*	*0.00*	*0.00*
Erythroselinum atropurpureum	*0.00*	*0.00*	*1*	*0.13*
Eucalyptus globulus	*0.00*	*2.75*	*0.00*	*0.27*
Euclea divinorum	*1.00*	*2.25*	*0.86*	*0.00*
Euphorbia ampliphylla	***3.62***	*0.00*	*0.00*	*0.00*
Ficus sur	*0.00*	***2.00***	*0.00*	*0.00*
Ficus sycomorus	*0.00*	*1.38*	*0.00*	*0.00*
Galinsoga parviflora	*0.00*	*0.00*	*0.00*	*0.53*
Guizotia schimperi	*1.08*	*0.00*	*0.00*	*0.73*
Halleria lucida	***3.08***	*0.00*	*0.00*	*0.00*
Heliotropium zeylanium	*0.00*	*0.00*	*0.29*	*0.00*
Hyparrhenia hirta	*0.00*	*1.38*	*0.57*	*0.80*
Hypericum revolutum	*0.00*	*0.00*	*1.50*	*0.00*
Indigofera spicata	*0.00*	*0.00*	*0.00*	***1.13***

Table 2 con't…

Jasminum abyssinicum	*0.00*	*1.00*	*0.64*	*0.00*
Justicia ladanoides	*0.00*	*0.00*	*0.29*	*0.00*
Maesa lanceolata	*0.00*	*0.00*	***2.36***	*0.00*
Maytenus arbutifolia	*2.92*	*2.38*	*3.21*	*1.67*
Myrsine africana	*2.31*	*0.00*	*3.57*	*0.20*
Ocimum lamiifolium	*0.00*	*0.00*	*0.43*	*0.00*
Olea europaea	*0.00*	*2.50*	*4.07*	*2.67*
Osyris quadripartita	*0.00*	*3.75*	*1.36*	*0.87*
Pennisetum riparium	*0.00*	*0.00*	*0.86*	*1.40*
Pennisetum villosum	*0.00*	*0.00*	*0.86*	*0.53*
Phytolacca dodecandra	*0.00*	*0.00*	*1.43*	*0.00*
Podocarpus falcatus	*0.00*	*3.50*	*0.43*	*1.07*
Premna schimperi	*3.00*	*3.88*	*3.14*	*1.40*
Pterolobium stellatum	*3.38*	*3.13*	*6.00*	*2.80*
Rhamnus staddo	*0.00*	*0.00*	*0.00*	*1.00*
Rhoicissus tridentata	*0.54*	*1.00*	*0.21*	*0.20*
Rhus glutinosa	*0.00*	*4.63*	*1.86*	*0.53*
Rhynchosia eleganse	*0.00*	*0.50*	*0.00*	*0.00*
Ricinus communis	*0.00*	*0.00*	*0.00*	*0.8*
Rubia cordifolia	*0.00*	*0.00*	*0.36*	*0.00*
Rubus apetalus	*0.00*	*0.00*	*0.00*	***1.53***
Rumex nepalensls	*0.00*	*0.38*	*0.00*	*0.00*
Salix mucronata	*0.00*	*1.28*	*0.00*	*0.00*
Stephania abyssinca	*0.00*	*0.50*	*0.86*	*0.73*
Syzygium guineense	*0.00*	*0.00*	*0.07*	*0.07*
Thalictrum rynchocarpum	*0.00*	*0.00*	*0.00*	*0.40*
Trifolium bilineatum	*2.31*	*0.38*	*2.57*	*0.67*
Vepris dainelli	*0.00*	*1.63*	*0.00*	*0.00*

4.4 Species Diversity, Evenness and Richness

The result of computation of Shannon Wiener diversity index shows that, Community type 2 has the highest species diversity followed by communities 3, 4 and 1(Table 3). Species richness is among the most widely used measures of diversity. Species richness refers to the number of species present in a given area or habitat (Tivy, 1993). Species evenness measures the equity of species in a given sample area or evenness is a measure of abundance of the different species that make up the richness of the area(Mueller-Dombis and Ellennberg, 1974).According to Magurran (1988), species diversity is both a function of the number of species (Richness), and the evenness (Relative or proportional abundance of species). Therefore, high species richness (56) and high evenness (0.920832) contributed to highest diversity of community type 2(3.706671) (Table 3). The highest species diversity of community 2 attributed to low anthropogenic activity and favorable environmental condition. Community type 3 has the highest species richness (68) followed by community type 4, 2 and 1(Table 3). Even though community type 1 has the least species diversity and richness, it has the highest species evenness. The lowest species diversity of community type 1 may be due to high human interference like agriculture expansion and grazing. The value of the Shannon-Weiner index usually lies between 1.5 and 3.5 although in exceptional case, the Value can exceed 4.5 (Pielou, 1969).

Table 3 Shannon Wiener diversity index

Community types	Richness	Diversity index(H')	Evenness (H'/H'max)
1	22	2.884509	0.933183
2	55	3.706671	0.920832
3	65	3.66125	0.867696
4	59	3.624393	0.885219

4.5 Similarity Among Plant Communities

In order to determine the similarities among plant communities of the study area, similarity ratios were computed following Sorensen`s similarity coefficient (Table 4). Accordingly, Community types 2 and 4 had the highest similarity ratio (0.3936) followed by community types 3 and 4(0.3673) which might be attributed to the existence of these communities with in almost similar altitudinal range, sharing similar soil types, same extent of anthropogenic activities. In contrast, Community types 1 and 2 had the least similarity ratio (0.2376). Computation of Sorensen's similarity coefficient revealed that Community 1 shares less similarity with other communities; this might be due to the fact that the variation of community 1 from other community types interms of the extent of anthropogenic activities, soil moisture, extent of rainfall and temperature.

Table 4: Sorensen similarity coefficient among community types

Communities	1	2	3	4
1				
2	0.2376			
3	0.2689	0.3333		
4	0.2957	**0.3936**	0.3673	

4.6 Density of Tree and Shrub species

The density of tree/shrub species of the study area with DBH greater than 2 cm is shown in Table 5. The overall density of tree/shrub species which have DBH >2 cm was 874 individual/ha. About 68.94% individuals were classified under lower DBH class i.e.2-7 cm followed by 16.99% individuals which were categorized under 8-13cm DBH class (Table 5). Generally, the pattern shows that as DBH increases the number of individuals' decreases. The number of individuals decreases as DBH increases because as plant species grow in size or mature enough, the local communities exploit for various purposes.

Therefore, the dominance of small sized individuals indicates that the area was under heavy degradation and currently in a stage of secondary development. With regard to plant species *Carissa spinarum, Pterolobium stellatum, Premna schimperi, Olea europia* subsp. *cuspidata* and *Maytenus arbutifolia, Calpurnia aurea* and *Clausena anisata* contributed to the largest proportion of individuals. *Carissa spinarum* and *Pterolobium stellatum* with DBH <2 cm contributed 16.67 % and 16.15% to the lowest DBH class respectively. These two species dominated the lower DBH classes i.e. <2 cm and 2-7 cm. In contrast *Grewia ferruginea* and *Podocarpus falcatus* are species with few individuals in lower DBH classes (Appendix 5). This might be attributed to anthropogenic activity such as grazing pressure in the study area. The highest DBH class (>26 cm) is represented by *Croton macrostachyus, Olea europaea subsp. cuspidata* and *Podocarpus falcatus*. From these *Croton macrostachyus* contributed the highest percentage of individuals (43.75%)(Appendix 5)

Table 5 Density of woody species with different DBH classes

DBH classes	Density ha-1	Percentage (%)
2-7cm	602.5	68.94
8-13cm	148.5	16.99
14-19cm	71.5	8.18
20-25cm	32.5	3.72
>26cm	19	2.17

4.7 Frequency

Frequency is the number of quadrats in which a given species occurred in the study area. Frequency is the indication of homogeneity and heterogeneity of given vegetation in which the higher number of species in higher frequency classes and low number of species in lower frequency classes show similar species composition while large number of species in lower frequency classes and small number of species in higher frequency classes indicates higher heterogeneity (Lambrecht, 1989).

Analysis of the frequency distribution indicated that *Carissa spinarum, croton macrostachyus* and *Pterolobium stellatum* were found to be with the highest frequency, indicating good distribution in the study area because of wise use of thse species by local communities. *Carissa spinarum* occurred in 43 quadrats, followed by *Croton macrostachyus* which was found in 40 quadrats and *Pterolobium stellatum* which was occurred in 37 quadrats frequency. This indicates that the above three species were only absent from a few quadrats. In contrast, among the dominant woody species of the study area, there were also species occurring in few quadrats. These are, *Podocarpus falcatus* which was found in 8 quadrats (16%frequency), *Grewia ferruginea* and *Euclea divinorum* which occurred in 12 quadrats (24% frequency each)(Table 6). This indicates the above three species were less in distribution in the study area compared with more frequent species.This emanate from high exploitation of these species for various purposes by local communities.

Table 6 Frequency distribution of dominant trees/shrubs of the study area.

Species	Frequency	%Frequency	Relative frequency (%)
Carissa spinarum	43	86	11.38
Croton macrostachyus	40	80	10.58
Pterolobium stellatum	37	74	9.79
Premna schimperi	32	64	8.47

Table 6 con't…

Maytenus arbutifolia	29	58	7.67
Albizia schimperiana	24	48	6.35
Acacia abyssinica	23	46	6.35
Calpurnia aurea	24	48	6.08
Olea europaea	23	46	6.08
Myrisine africana	20	40	6.08
Osyris quadripartita	13	26	5.29
Rhus glutinosa	15	30	3.97
Grewia ferruginea	12	24	3.17
Euclea divinorum	12	24	3.17
Clausena anisata	23	46	2.12
Podocarpus falcatus	8	16	2.12

4.8 Basal area

The total basal area of the study area as calculated from DBH data was 8.75m^2ha^{-1}. From the total basal area of the study area about 88.68% was contributed by only 16 dominant woody species. The most dominant species with high basal area was *Croton macrostachyus* (1.76m^2ha^{-1})(20.11%),*Olea europaea subsp.cuspidata 0.92* m^2ha^{-1}(10.51%) *and Acacia abyssinica* 0.*83*(9.49%).

Eventhough *Carissa spinarum* was the dominant species with high density, frequency and cover abundance study; its contribution to basal area was not so much because the stem of the species is very thin. In contrary, *Podocarpus falcatus* which had low density contributed high to basal area. This indicates that species with the highest basal area do not necessarily have the highest density, indicating size difference between species (Tamrat Bekele, 1994). Basal area provides a better measure of the relative importance of tree species than simple stem counts (Cain and Castro, 1959 cited in Tamrat Bekele, 1994); species with the largest contribution in basal area can be considered the most important trees in the forest.

Table 7 Basal area (BA) of dominant woody species in the study area.

Plant Species	BA m^2ha^{-1}	%	Habit
Croton macrostachyus	1.76	20.11	T
Olea europaea	*0.92*	10.51	T
Acacia abyssinica	0.83	9.49	T
Podocarpus falcatus	0.77	8.8	T
Calpurnea aurea	0.66	7.54	T
Albizia schimperiana	0.54	6.17	T
Grewia ferruginea	0.49	5.6	T
Rhus glutinosa	0.41	4.69	T
Premna schimperi	0.35	4	S
Maytenaus arbutifolia	0.27	3.09	S
Osyris quadripartita	0.2	2.29	S
Pterolobium stellatum	0.15	1.71	T
Clausena anisata	0.13	1.49	T
Carissas spinarum	0.1	1.14	S
Euclea divinorum	0.1	1.14	S
Myrisine africana	0.08	0.91	S

4.9 Diameter at Breast Height(DBH)

For the description of vegetation structure DBH was measured at 1.3 m using meter-tape for shrubs and trees that had a DBH equal or greater than 2 cm (Martin, 1995). Accordingly, DBH classes were grouped in to six classes. Namely, <2 cm, 2-7 cm, 8-13 cm, 14-19 cm, 20-25 cm and >26 cm. The first two lower DBH classes (<2 cm, 2-7 cm) contributed high individual density. Accordingly, about 51.71% individuals belong to lowest DBH class (<2 cm) and 33.14% individuals were categorized under 2-7 cm DBH class. The distribution of woody species in four remaining DBH classes i.e 8-13 cm, 14-19 cm, 20-25 cm and >26 cm are 8.17%, 3.93%, 1.79% and 1.27% respectively. Therefore, the total number of trees/shrubs in each DBH classes decreased with an increase in DBH classes (Figure 5). This relationship was also observed in Chilimo and Menagesha forests (Tamrat Bekele, 1993). The distribution of individuals in six DBH classes depicts the vegetation structure of shrubland vegetation of the study area that shows reversed *J* shape.This suggests that the majority of the species had the highest number of individuals in lower DBH classes which imply that the shrubland vegetation has good reproduction potential. Conversely, it should be noted that when the entire DBH class distribution of the shrub land vegetation is assessed on a species basis, different population dynamics for different species were revealed. For example, the distribution pattern of *Podocarpus falcatus* and *Croton macrostachyus* in different DBH classes is irregular in shape. This might be attributed to anthropogenic activity because of the economic importance of these plants. The distribution of *Podocarpus falcatus* tend to decrease at higher DBH classes as a result of high exploitation of the plant for construction, timber exploitation, fire wood etc. Furthermore, the less number of individuals belonging to lower DBH classes suggests that *Podocarpus falcatus* is low enough for regeneration capacity. Generally this pattern shows less reproduction as well as recruitment.

The number of individuals of *Croton macrostachyus* decreases gradually with increasing DBH for the first four DBH classes and shows increment at fifth DBH class, and then finally decreased for the highest DBH class. These might be attributed to selective removal of individuals for purpose of construction, fuelwood, and for other purposes. Generally, this pattern shows good reproduction but recruitment is hampered.

The Majority of the species shows reversed J shape, for example, *Acacia abyssinica* and *Rhus glutinosa* show this pattern. The individuals gradually decrease from lower DBH classes to Higher DBH classes. Stems having high diameter are low in number because the local people exploit these species for fuel wood and charcoal, building of fence, etc. However, the regeneration and recruitment potential of *Acacia abyssinica* and *Rhus glutinosa* is promising.

The other pattern of population structure observed was partial u-shape. Some of the representative species of this pattern are *Juniperus procera, Pittosporum Viridiflorum* and *Ficus sur*. *Juniperus procera* is the economically important species that is severely threatened in the study area. It is absent from the second and fifth DBH classes (Figure 6). Furthermore, it is also represented by few individuals. Therefore, unless effective conservation and management measurement are taken, *Juniperus procera* might go extinct in the study area in near future.

For few woody species, J-shaped pattern population structure was observed. In this case, as DBH increases, the number of individuals increases. The lower DBH classes are represented by few individuals than higher DBH classes which impily that less regeneration capacity. *Ficus sycomorus, Bersama abyssinica and Rhus vulgaris* are the woody species showing this pattern.

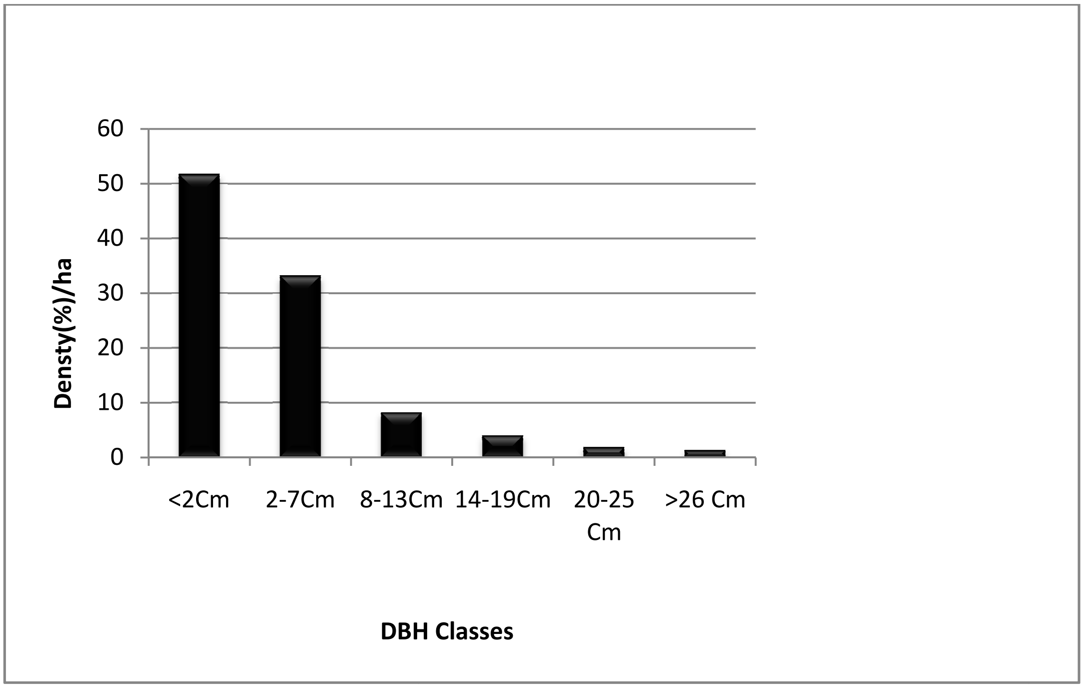
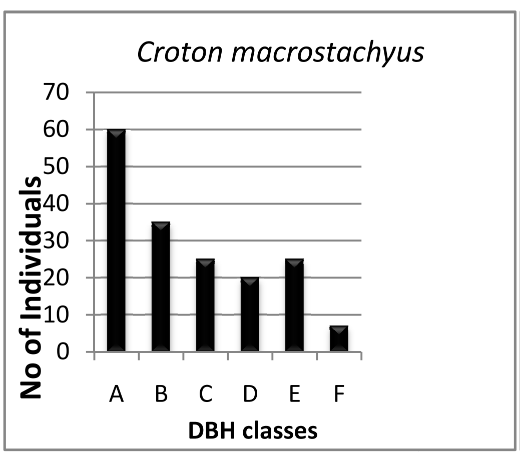
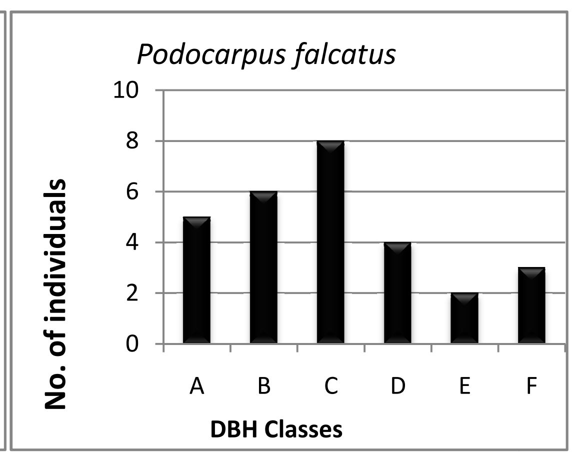


Figure 4. Density (%) of woody species/ha at different DBH classes.





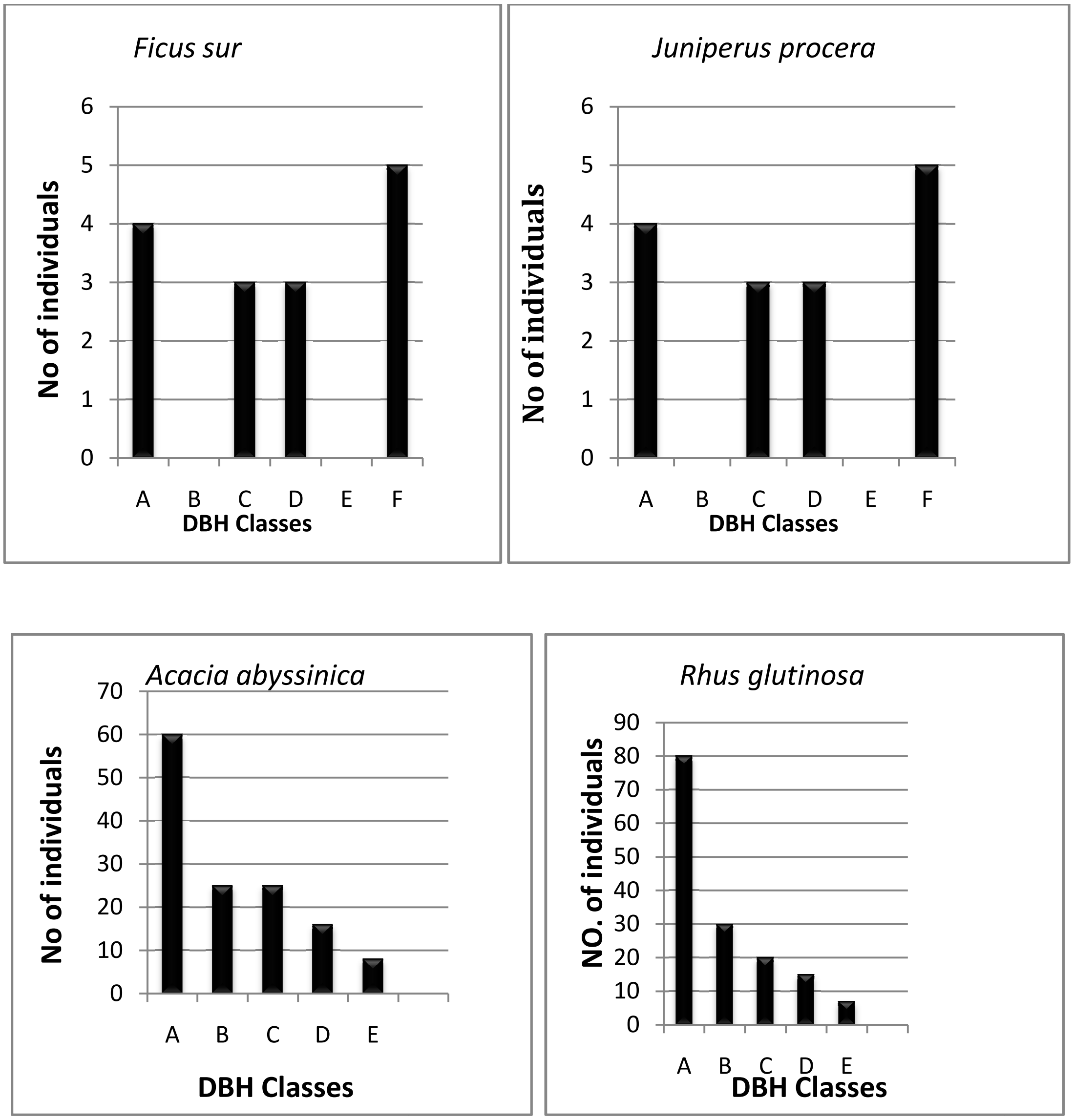


Figure 5: Population structure of some selected woody species

Where, A=<2cm,B= 2-7cm, C=8-13cm, D=14-19cm, E=20-25cm and F=>26cm

4.10 Height Classes of Woody Species

The density distribution of height classes of trees and shrubs at shrub land vegetation along the escarpments between Addis Alem and Wolenkomi is shown Figure 7. The majority of individual species were included under lower height classes. Accordingly, about 49.85% individuals/ha had height less than 2 m followed by 31.92% individuals/ha which was categorized under 2-5 m height class. Only 1.35% individuals/ha attain height greater than 18 m. Generally, height class distribution shows similar pattern with that of DBH class distribution which is reversed J shape. However, there would be variation with respect to individuals of the same species when analyzed separately. Hence, the study showed that the number of individuals decreased as the height of the individuals increased indicating long time disturbance by anthropogenic activity such as deforestation and grazing but currently the vegetation has good reproduction and recruitment potential. Such result was also observed in Chilmo forest by Tamrat Bekele (1993). Height reflects something about the different growth phase or ages of tree species. It is a good indicator of the role of a species as each of them occupies a different layer and practically determines the vertical structure of the stand (Pascal *et al.,* 1996; cited in Fayera Abdena, 2010).

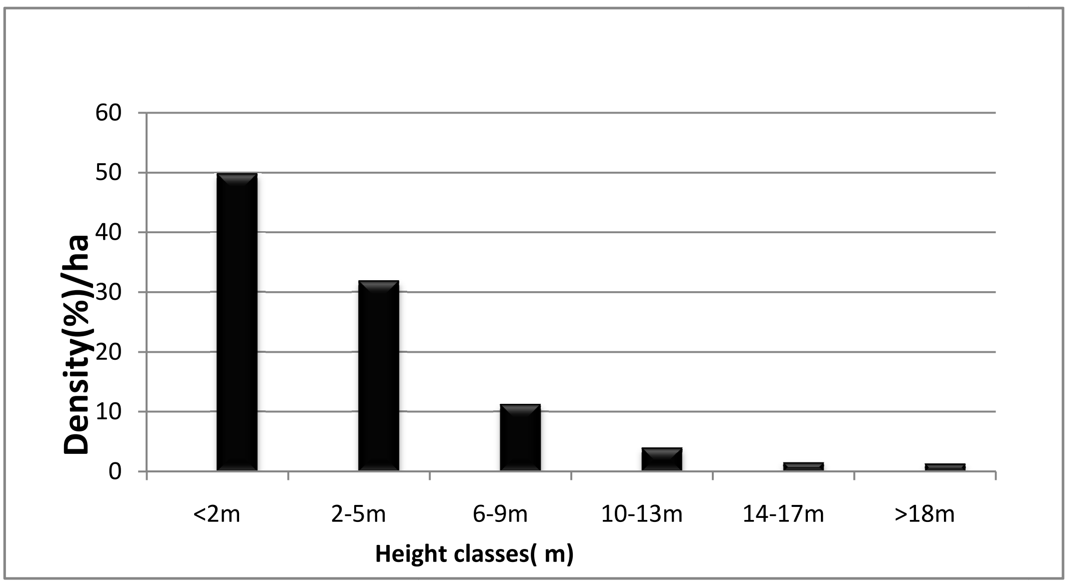


Figure 6 Density (%)/ha of tree/shrub in different height classes.

4.11 Importance Value Index(IVI)

Importance Value Index (IVI) of dominant woody species of the area was calculated by adding up three parameters i.e.Relative density, Relative frequency and Relative dominance for each species (Table 8). The greatest IVI reflects the degree of dominancy and abundance of a given species in relation to the other species in the area. It is also used for setting priority /ranking species management and conservation pactices and helps to identify their sociological status (structure) in a certain plant community as dominant or rare species (Kent and Coker, 1992).The computation of Importance Value Index (IVI) showed that *Croton macrostachyus (39.58*%), *Carissa spinarum (*28%), *Olea europaea subsp. cuspidata (*26.16%), *Pterolobium stellatum* (25.03%), *Acacia abyssinica (*23.6%) were the most important species of the study area by contributing 47.46% of total IVI. Conversely, *Euclea divinorum* (7.37%), *Osyris quadripartita (*8.95%), *Myrisine africana*11.05*% and Grewia ferrugenia (12.57%)* are species with low IVI values compared with the above five most dominant species.Therefore, these species need more conservation and management practices than other dominant species of the area. In terms abundance value *Carissa spinarum* is the most abundant species in the study area (Synoptic Table). However, in terms of IVI value *Carissa spinarum* is surpassed by *Croton macrostachyus*. This might be due to the fact that abundance is not always an indicator of the importance of a plant in a community (Dereje Denu, 2006).

Table 8 Importance Value Index of the most dominant tree/shrub species of the study area.

Species	Relative density (%)	Relative frequency (%)	Relative dominance (%)	*IVI (%)*	IVI Rank
Croton macrostachyus	6.31	10.58	22.69	39.58	1
Carissas spinarum	15.38	11.38	1.24	28	2
Olea europaea	8.23	6.08	11.85	26.16	3
Pterolobium stellatum	13.3	9.79	1.94	25.03	4
Acacia abyssinica	6.54	6.35	10.71	23.6	5
Premna schimperi	7.89	8.47	4.52	20.88	6
Maytenaus arbutifolia	7.77	7.67	3.48	18.92	7
Calpurnea aurea	5.35	6.08	8.54	19.97	8
Albizia schimperiana	4.23	6.35	6.93	17.51	9
Podocarpus falcatus	1.13	2.12	9.94	13.19	10
Clausena anisata	6.14	6.08	1.7	13.92	11
Rhus glutinosa	4.06	3.97	5.29	13.32	12
Grewia ferruginea	3.1	3.17	6.27	12.54	13
Myrisine africana	4.73	5.29	1.03	11.05	14
Osyris quadripartita	2.93	3.45	2.58	8.96	15
Euclea divinorum	2.91	3.17	1.29	7.37	16
Total	100	100	100	300	

4.12 Conclusion and Recommendations

4.12.1 Conclusion

The shrubland vegetation along the escarpment between Addis Alem and Wolenkomi has diverse plant species (shrubs, trees, herbs and climbers). The result obtained from the study area shows that 101 plant specimens belonging to 88 genera and 48 families were collected. Out of the species recorded, Angiospems were estimated to cover 96%; gymnosperms contributed 3% whereas only one fern species was recorded from the site contributing 1%. From the collected specimens, shrubs were estimated to cover 35.64%, herbs 34.65%, trees 22.77%, climbers 5.94% and fern 1%. Fabaceae was the most dominant family with 11 species followed by Asteraceae with ten species and Poaceae with nine species. According to data analyzed by hierarchical cluster analysis, the vegetation of the study area was classified into four plant community types which had varying degrees of species richness, diversity and evenness. They are:

Community type 1. *Euphorbia ampliphylla-Halleria lucida* community type which is distributed within altitudinal range of 2160-2248 and comprised of 13 plots and 22 species

Community type 2. *Dovyalis abyssinica-Ficus sur* community type which is distributed between the altitudinal range of 2196-2283 and comprised of 8 plots and 57 species.

Community type 3. *Caparris tomentosa - Maesa lanceolata* community type which is distributed between the altitudinal range of 2145-2282m and comprised of 14 plots and 65 species.

Community type 4. *Rubus apetalus-Indigofera spicata* community type distributed between the altitudinal range of 2137-2289m and comprised of 15 plots and 59 species.

The variation observed in species composition and diversity among communities might be attributed to different factors such as climatic factors, soil type and composition, altitude, anthropogenic factors, etc., out of this altitude might have played significant role.

The total basal area of the study area as calculated from DBH data was 8.75 m^2ha^{-1}. The area is found to possess shrub species dominating the area with scattered trees species. The overall density of tree/shrub species which had DBH >2cm was 874 individual/ha. The density of trees/shrubs decreased with increasing DBH and height indicating the dominance of small-sized individuals in the area. This impilies the area was heavily exploited and at present time it exists in secondary development. The computation of IVI shows *Croton macrostachyus, Carissa spinarum, Olea europaea subsp. cuspidata, Pterolobium stellatum* and *Acacia abyssinica* are the most dominant species of the area.

4.12.2 Recommendations

Vegetation is a vital resource for human being and generally for all living things. The oxygen (0_2) we inhale, the water (H_2O) we drink, and the food we eat directly or indirectly obtained from the contribution of plants. Therefore, it would not be exaggeration if we say, our life on the planet earth is impossible without plants. However, this important natural resource has been under threat from human interference beginning from ancient time to the present. From this study it was observed that the threat to the vegetation of the area between Addis Alem and Wolenkomi is severe as in other places of Ethiopia. Hence, the following recommendations are put forward for the study area.

- It is better if awareness creation to local people on sustainable utilization of plants is done.
- The government should implement rules and regulations to take measures on those people who illegally clear the vegetation for various purposes.
- It is better if reforestation measures are taken by governments, both local and regional, wherever necessary by participating the local people.
- The local people, government and non-governmental organization should

cooperate in conserving and enhancing sustainable use of vegetation.

- The planning and management of vegetation should be based on research outcomes. Research plays a vital role in providing the necessary information, identifying the problems and seeking the solution. Therefore, further studies are required for the study area and also to fill the gap of this work such as analysis of soil samples.

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APPENDICES

Appendix 1. Geographic co-ordinates, altitudes and richness of each plot of the study area

Quadrats	Latitude	longitude	Altitude	Richness	Site
1	09^{0}01.965′	038^{0}21.920’	2145	35	Tulu korma
2	09^{0}01.785’	038^{0}21.684’	2150	25	Tulu Korma
3	09^{0}01.067’	038^{0}21.315’	2156	15	Tulu Korma
4	09^{0}01.047’	038^{0}21.455’	2171	19	Tulu Korma
5	09^{0}01.051’	038^{0}21.564	2175	15	Tulu Korma
6	09^{0}01.998’	038^{0}21.349’	2196	7	Tulu Korma
7	09^{0}01.678’	038^{0}21.345’	2216	14	Tulu Korma
8	09^{0}01.342’	038^{0}21.747’	2171	21	Tulu Korma
9	09^{0}01.147′	038^{0}21.660’	2167	14	Tulu Korma
10	09^{0}01.155’	038^{0}21.669’	2178	12	Tulu Korma
11	09^{0}01.153’	038^{0}21.671’	2185	10	Tulu Korma
12	09^{0}01.171’	038^{0}21.640’	2181	12	Tulu Korma
13	09^{0}01.167′	038^{0}21.589’	2186	16	Tulu Korma
14	09^{0}01.200’	038^{0}21.561’	2137	10	Tulu Korma
15	09^{0}01.973’	038^{0}22.586’	2264	25	KareAba Tafa
16	09^{0}01.965’	038^{0}22.632’	2282	17	KareAba Tafa

17	09^{0}01.965’	038^{0}22.632’	2283	15	KareAba Tafa
18	09^{0}01.988’	038^{0}22.631’	2289	9	KareAba Tafa
19	09^{0}01.951’	038^{0}22.647’	2278	12	KareAba Tafa
20	09^{0}01.961’	038^{0}22.621’	2282	20	Tulu Korma
21	09^{0}01.377’	038^{0}22.617’	2191	18	Tulu Korma
22	09^{0}01.162’	038^{0}21.858’	2197	15	Tulu Korma
23	09^{0}01.136’	038^{0}21.843’	2206	22	Hontu Aba Garo
24	09^{0}01.296’	038^{0}21.839’	2207	19	Hontu Aba Garo
25	09^{0}01.317’	038^{0}21.645’	2210	13	Hontu Aba Garo
26	09^{0}01.423’	038^{0}21.650’	2210	15	Hontu Aba Garo
27	09^{0}01.473’	038^{0}21.675’	2213	21	Sororoand Negade
28	09^{0}01.294’	038^{0}21.838’	2222	21	Sororoand Negade
29	09^{0}01.352’	038^{0}21.725	2225	27	Sororoand Negade
30	09^{0}01.369’	038^{0}21.725	2228	13	Sororoand Negade
31	09^{0}01.385’	038^{0}21.729’	2237	17	Sororoand Negade
32	09^{0}01.390’	038^{0}21.740’	2238	15	Sororoand Negade
33	09^{0}01.410’	038^{0}21.780’	2240	18	Kimoye
34	09^{0}01.419’	038^{0}21.788’	2244	12	Kimoye
35	09^{0}01.260’	038^{0}21.559’	2179	14	Kimoye

36	09^{0}01.275’	038^{0}21.588’	2195	17	Kimoye
37	09^{0}01.319’	038^{0}21.552’	2192	11	Kimoye
38	09^{0}01.330’	038^{0}21.560’	2192	16	Wolenkomi
39	09^{0}01.345’	038^{0}21.571’	2195	11	Wolenkomi
40	09^{0}01.425’	038^{0}20.927’	2160	14	Wolenkomi
41	09^{0}01.432’	038^{0}20.887’	2170	12	Wolenkomi
42	09^{0}01.463’	038^{0}20.867’	2194	12	Wolenkomi
43	09^{0}01.478’	038^{0}20.864’	2196	15	Wolenkomi
44	09^{0}01.492’	038^{0}20.850’	2205	13	Wolenkomi
45	09^{0}00.544’	038^{0}15.884’	2202	14	Wolenkomi
46	09^{0}00.545’	038^{0}15.875’	2215	15	Wolenkomi
47	09^{0}00.554’	038^{0}15.865	2236	13	Wolenkomi
48	09^{0}00.555’	038^{0}15.857’	2238	14	Wolenkomi
49	09^{0}00.553’	038^{0}15.846	2242	14	Wolenkomi
50	09^{0}00.560′	038^{0}15.834’	2248	16	Wolenkomi

Appendix 2. Species list collected from the study area between Addis Alem and Wolenkomi (Ha=habit,S = shrub, T = tree, H = herb, C = climber , Vernacular name in Afan Oromo)

No	Scientific name	Family	Ha	Vernacular name	Coll.no
1	*Andropogon* sp.	Poaceae	H	Gurra hantuutaa	023
2	*Acacia abyssinica* Hochst. ex Benth.	Fabaceae	T	Laaftoo	40
3	*Acanthus sennii* Chiov.	Acanthaceae	s	Kosorruu	53
4	Achyranthes aspera L.	Amarantaceae	H	Maxxannee	92
5	*Albizia schimperiana* Oliv.	Fabaceae	T	Imalaa	14
6	*Andropogon abyssinicus* Fresen.	Poaceae	H	Baallammii	89
7	*Arundo donax L*.	Poaceae	H	Shomboqqoo	84
8	*Asparagus africanus* Lam.	Asparagaceae	S	Sariitii	9
9	*Asplenium aethiopicum*(Burm.f.)Bech	Aspleniaceae	F	-	37
10	*Bersama abyssinica* Fresen.	Melianthaceae	T	Lolchiisaa	69
11	*Bidens macroptera* (Sch.-Bip. Ex Chiov.) Mesfin	Asteraceae	H	Adaa	93
12	*Calpurnea aurea* Benth.	Fabaceae	T	Ceekaa	17

13	*Caparris tomentosa* Lam.	Capparidaceae	S	-	43
14	*Carissa spinarum* L.	Apocynaceae	S	Agamsa	2
15	*Clausena anisata* (Willd.) Benth.	Rutaceae	S	Ulmaayii	11
16	*Clematis hirsuta* Perr & Guill.	Ranunculaceae	c	Hidda fiitii	5
17	*Clerodendrum myricoides* (Hochst.) Vatke	Lamiaceae	S	maraasisaa	4
18	*Conyza bonariensis* (L.) Cronq.	Asteraceae	H	Hartuu	51
19	*Conyza stricta* Willd.	Asteraceae	H	-	55
20	*Crassocephalum macropappum* (Sch. Bip. ex A. Rich.) S. Moore	Asteraceae	H	Qadaaddoo	32
21	*Crotolaria spinosaHochst.ex Benth*	Fabaceae	S	-	105
22	*Croton macrostachyus* Del	Euphorbiaceae	T	Bakkanniisa	49
23	*Cucumis ficifolius*.A. Rich.	Cucurbitaceae	C	Hoolotoo	104
24	*Cupressus lusitanica* Miller	Cupressaceae	T	Gaattiraa	65
25	*Cynodon dactylon* (L.) Pers.	Poaceae	H	Coqorsa	101
26	*Cyperus fischerianus A. Rich. (1851)*	Cyperaceae	H	Qunnii	87

27	*Delphinium dasycaulon Fres. /*	Ranunculaceae	H	-	91
28	*Dodonaea angustifolia* L.f.	Sapindaceae	S	Ittacha	47
29	*Dovyalis verrucosa* (Hochst.)Warb	Flacourtaceae	S	Mixmixxaa	21
30	*Dovyalis abyssinica(A.Rich.)Warb.*	Flacourtiaceae	S	Kolfaa	66
31	*Ekebergia capensis* Sparrm.	Meliaceae	T	Somboo	72
32	*Erythrina brucei* Schweinf.	Fabaceae	T	Waleensuu	97
33	*Erythroselinum atropurpureum (Hochst. exA. Rich.) Chiov.*	Apiaceae	H	Insilaalee	42
34	*Eucalyptus globulus* Labill.	Myrtaceae	T	Baargamoo	59
35	*Euclea divinorum* Hiern.	Ebenaceae	S	Mi'eessaa	27
36	*Euphorbia ampliphylla* Pax	Euphorbiaceae	T	Adaamii	110
37	*Euphorbia platyphyllos L.*	Euphorbiaceae	H	Ichima	50
38	*Ficus sur* Forssk.	Moraceae	T	Harbuu	76
39	*Ficus sycomorus*	Moraceae	T	Qilxuu	78
40	*Galinsoga quadriradiata Ruiz & Pavon.*	Asteraceae	H		70

41	*Glycine weghtii (Wight& Am.) Verde.*	Fabaceae	C	Hidda Hantuutaa	34
42	*Grewia ferruginea* Hochst. ex A. Rich.	Tiliaceae	T	Dhoqonuu	10
43	*Guizotia schimperi* Sch.Bip.ex Walp.	Asteraceae	H	Keelloo	94
44	*Halleria lucida* L.	Scrophulariaceae	S	Qamaxxee	26
45	*Heliotropium zeylanium*(Burm.f,)Lam	Boragenaceae	H	Maxxannee	30
46	*Hygrophila schulli* (Hamilt.)MR. & S.M Almeida	Acanthaceae	H	KORATII-SARE	96
47	*Hyparrhenia hirta* (L.) Stapf.	Poaceae	H	Citaa/Sambaleexa	41
48	*Hypericum revolutum* Vahl	Clusiaceae	S	Aannannoo	48
49	*Indigofera spicata* Forssk.	Fabaceae	S	-	106
50	*Jasminum abyssinicum* Hochst. ex DC.	Oleaceae	C	Hidda Ichilbee	20
51	*Juniperus procera* L.	Cupressaceae	T	Gaattiraa	58
52	*Justicia ladanoides* Lam.	Acanthaceae	H	-	45
53	*Justicia schimperana* (Hochst. ex Nees) T.Anders.	Acanthaceae	S	Dhummuugaa	68

54	*Kalanchoe petitiana* A.Rich.	Crassulaceae	H	Bosoqqqee	19
55	*Kohautia coccinia* Royle.	Rubiaceae	H		7
56	*Leucas martinicensis* (Jacq.)R.Br.	Lamiaceae	H	-	100
57	*Lippia adoensis* Hochst.ex Walp.	Verbenanaceae	S	Kusaayee	54
58	*Maesa lanceolata* Forssk.	Myrsinaceae	T	Abbayyii	46
59	*Maytenus arbutifolia(A.Rich.)Wilczek*	Celastraceae	S	Qarxammee	3
60	*Millettia ferruginea (Hochst.) Bak.*	Fabaceae	T	Birbirraa	64
61	*Myrsine africana* L.	Myrsinaceae	S	Qacamoo	18
62	*Ocimum lamiifolium* Hochst. ex Benth.	Lamiaceae	S	Qoricha michii	80
63	*Olea europaea L. subsp. cuspidata* (Wall. ex. G. Don.) Cif.	Oleaceae	T	Ejersa	12
64	*Osyris quadripartita* Decn.	Santalaceae	S	Waatoo	28
65	*Pennisetum riparium* Hochst. ex A. Rich.	Poaceae	H	Migira	39
66	*Pennisetum thumbergi*	Poaceae	H	Migira saree	24

	Kunth.				
67	*Pennisetum villosum* Fresen.	Poaceae	H	Araddoo	6
68	*Phytolacca dodecandra* L` Herit.	Phytolaccaceae	S	Andoodee	81
69	*Pittosporum viridiflorum* Sims Pittosporaceae	Pittosporaceae	T	Daalachoo	16
70	*Plantago lanceolata* L.	Plantaginaceae	H	Sissii/asanda aboo	52
71	*Podocarpus falcatus*(Thunb.) R. B. ex. Mirb.	Podocarpaceae	T	Birbirsa	22
72	*Premna schimperi* Engl.	Lamiaceae	S	Urgeessaa	8
73	*Pterolobium stellatum* (Forssk.) Brenan	Fabaceae	S	Arangamaa	001
74	*Rhamnus staddo* A.Rich.	Rhamnaceae	S	Qadiidaa	67
75	*Rhoicissus tridentata (L. f.) Wild& Drummond*	Vitaceae	C	Hidda bofaa	103
76	*Rhus glutinosa* A. Rich. subsp.neoglutinosa (Gilbert)Gilbert)	Anacardiaceae	T	Xaaxessaa	13
77	*Rhus vulgaris* Meikle	Anacardiaceae	S	Laboobessaa	83
78	*Rhynchosia eleganse*	Fabaceae	H	-	56

	A.Rich.				
79	*Ricinus communis* L.	Euphorbiaceae	S	Qobboo	98
80	*Rosa abyssinica* Lindley	Rosaceae	S	Qaqawwee	31
81	*Rubia cordifolia* L.	Rubiaceae	H		99
82	*Rubus apetalus* Poir. /	Rosaceae	S	Goraa/Altufa	61
83	*Rumex nepalensis* Spreng	Polygonaceae	H	Shulxii	57
84	*Rytigynia neglecta* (Hiern) Robyns	Rubiaceae	S	Mixoo	29
85	*Salix mucronata* Thunb. (*s. subserrata* Willd.)	Salicaceae	T	Alaltuu	77
86	*Sanicula elata* Buch.-Ham.ex D.Don	Apiaceae	H	Gabbisaa	79
87	*Satureja abyssinica*(Benth.)Briq.	Lamiaceae	H	-	44
88	*Satureja punctata*(Benth.)	Lamiaceae	S	-	36
89	*Sida schimperiana* Hochst	malvaceae	S	Cifriggii/Guftee	15
90	*Solanum incanum* L.	Solanaceae	S	Hiddii	73
91	*Sporobolus pellucidus* Hochst.	Poaceae	H	Muriyyii	33
92	*Stephania abyssinca*(Dillon & A. Ri	Menispermaceae	C	Hidda kalaalaa	63

93	*Syzygium guineese* (Willd.) DC. subsp. *afromontanum* F.White	Myrtaceae	T	Baddeessa	95
94	*Thalictrum rynchocarpum.* Dill.&A.Rich	Ranunculaceae	H	-	88
95	*Tragia plukenetii A.RadcI.* Smith	Euphorbiaceae	H	-	38
96	*Trifolium bilineatum Fresen*	Fabaceae	H	Siddisa	25
97	*Vepris dainelli* (Pichi-serm.) Kokwaro.	Rutaceae	S	Hadheessaa	86
98	*Vernonia amygdalina* Del.	Asteraceae	T	Eebicha	71
99	*Vernonia auriculifera* Hiern*.*	Asteraceae	S	Reejjii	62
100	*Vernonia leopoldii* Vatke	Asteraceae	S	Sookee gogorrii	75
101	*Vernonia urticifolia* A.Rich.	Asteraceae	S	Monjor	60

Appendix 3. Family, genera and Species distribution of the study area.

No	Family	Number of genera	%	Number of species	%
1	Acanthaceae	3	3.41	4	3.96
2	Amaranthaceae	1	1.14	1	0.99
3	Anacardiaceae	1	1.14	2	1.98
4	Apiaceae	2	2.27	2	1.98
5	Apocynaceae	1	1.14	1	0.99
6	Asparagaceae	1	1.14	1	0.99
7	Aspleniaceae	1	1.14	1	0.99
8	Asteraceae	6	6.82	10	9.9
9	Boragenaceae	1	1.14	1	0.99
10	Capparidaceae	1	1.14	1	0.99
11	Celastraceae	1	1.14	1	0.99
12	Cluciaceae	1	1.14	1	0.99
13	Crassulaceae	1	1.14	1	0.99
14	Cucurbitaceae	1	1.14	1	0.99
15	Cupressaceae	2	2.27	2	1.98
16	Cyperaceae	1	1.14	1	0.99
17	Ebenaceae	1	1.14	1	0.99
18	Euphorbiaceae	4	4.55	5	4.95
19	Fabaceae	10	11.36	11	10.89
20	Flacourtaceae	1	1.14	2	1.98

21	Lamiaceae	5	5.68	6	5.94
22	Malvaceae	1	1.14	1	0.99
23	Meliaceae	1	1.14	1	0.99
24	Melianthaceae	1	1.14	1	0.99
25	Menispermaceae	1	1.14	1	0.99
26	Moraceae	1	1.14	2	1.98
27	Myrsinaceae	2	2.27	2	1.98
28	Myrtaceae	2	2.27	2	1.98
29	Oleaceae	2	2.27	2	1.98
30	Phytolaccaceae	1	1.14	1	0.99
31	Pittosporaceae	1	1.14	1	0.99
32	Plantaginaceae	1	1.14	1	0.99
33	Poaceae	6	6.82	9	8.91
34	Podocarpaceae	1	1.14	1	0.99
35	Polygonaceae	1	1.14	1	0.99
36	Rhamnaceae	1	1.14	1	0.99
37	Rosaceae	2	2.27	2	1.98
38	Rubiaceae	3	3.41	3	2.97
39	Ranunculaceae	3	3.41	3	2.97
40	Rutaceae	2	2.27	2	1.98
41	Salicaceae	1	1.14	1	0.99
42	Santalaceae	1	1.14	1	0.99

43	Sapindaceae	1	1.14	1	0.99
44	Scrophulariaceae	1	1.14	1	0.99
45	Solanaceae	1	1.14	1	0.99
46	Tiliaceae	1	1.14	1	0.99
47	Verbenaceae	1	1.14	1	0.99
48	Vitaceae	1	1.14	1	0.99

Appendix 4. Community types and their characteristics of the study area

Community Type	Dominant species in the community	Species Richness	Quadrats belonging in each community	Altitudinal range
1	*Carissa spinarum* *Croton macrostachyus* *Euphorbia ampliphylla* *Pterolobium stellatum* *Premna schimperi*	22	39,40,45,50,44,42,46,41,38,43,47,48,49	2160-2248m
2	*Rhus glutinosa* *Premna schimperi* *Osyris quadripartita* *Croton macrostachyus,* *Podocarpus falcatus*	57	30,32,6,27,2815,7,17	2196-2283m
3	*Pterolobium stellatum* *Carissa spinarum* *Olea europaea* sub sp. *Cuspidata* *Myrisine Africana* *Maytenus arbutifolia* *Acacia abyssinica*	65	8,9,10,22,20,21,3,5,16,4,24,2,23,1	2145-2282m
4	*Carissa spinarum* *Acacia abyssinica* *Croton macrostachyus* *Pterolobium stellatum* *Olea europaea L. sub sp. Cuspidata.*	59	29,31,14,12,13,25,26,11,18,34,33,35,19,36,37	2137-2289m

Appendix 5. Percentage distribution of dominant Woody Species of the study area based on DBH

Scientific name	DBH Classes					
	<2Cm	2-7Cm	8-13Cm	14-19Cm	20-25Cm	>26Cm
Croton macrostachius	3.13	2.91	8.14	13.42	32.05	43.75
Olea europaea	7.8	4.58	16.29	13.42	19.23	37.5
Acacia abyssinica	4.69	1.92	7.17	14.77	10.26	0
Podocarpus falcatus	0.26	0.5	2.61	2.68	2.56	18.75
Calpunnea aurea	6.77	5	9.77	12.08	5.13	0
Albizia schimperiana	6.2	3.33	9.77	10.07	12.82	0
Grewia fruginia	0	1.67	5.86	6.71	8.97	0
Rhus glutinosa	4.17	2.5	6.51	10.07	8.97	0
Premna schimperi	7.97	8.33	13.03	0	0	0
Maytenaus arbutifolia	7.97	5.83	13.03	16.78	0	0
Osyris quadripartita	3.13	3.33	3.91	0	0	0
Pterolobium stellatum	16.15	19.65	0	0	0	0
Clausena anisata	7.29	9.1	0	0	0	0
Carissas spinarum	16.67	22.73	0	0	0	0
Euclea divinorum	3.13	3.33	3.91	0	0	0
Myrisine africana	4.69	5.33	0	0	0	0