Ecological Study of the Shrubland Vegetation around Ambo, West Shewa Zone of Oromia National Regional State, Central Ethiopia

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This is to certify that the thesis prepared by Belete Kebede, entitled: Ecological *Study of the Shrubland Vegetation around Ambo, Oromia National Regional State, Central Ethiopia* in partial fulfillment of the requirements for the Degree of Master of Science (Plant Biology and Biodiversity Management: Plant Ecology) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Ecological Study of the Shrubland Vegetation around Ambo, West Shewa Zone of Oromia National Regional State, Central Ethiopia

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Addis Ababa University, 2012

The study area is located around Ambo, West Shewa Zone of Oromia Regional State. This study was carried out with the aim of compiling floristic composition, population structure and community types. Fifty two, 20 m x 20 m quadrats were selected and all the plants in the quadrats were recorded. The cover abundance values were estimated. DBH, height, and density count for woody species in all the quadrats were registered. A total of 110 species belonging to 98 genera and 48 families were recorded from 52 sample plots and identified at the National Herbarium (ETH), Addis Ababa University. The *Asteraceae* family was represented by the highest number of species (16) followed by *Fabaceae* (13) and *Poaceae (*8). Five community types were identified and described. The plant communities were named after two or three of the dominant species and/or characteristic species selected by their synoptic value. The plant community differed in species diversity, frequency of occurrence and botanical composition of species. The *Rosa abyssinica-Galium aparinoides* community type had the highest species diversities whereas *Vernonia amygdalin-Erythrina brucei-Juniperus procera* and *Bidens pilosa - Microlepia strigosa - Capparis tomentosa* communities had the lowest. Shannon-Wiener diversity indices were computed to measure species diversity and it revealed that species diversity is high in communities 1, 5, 4, 2 and 3 respectively. This is probably due to high rate of disturbance in the communities. The natural environment is under threat from various farming and grazing practices. Based on the result of the study, continuous discussion between local communities and various stakeholders as well as detailed ecological studies were recommended.

Keywords/phrases: Cluster analysis, Diversity, Dominant species, Floristic composition, Vegetation, Vegetation structure

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DEDICATION

This thesis is dedicated to my lovely father Ato Kebede Sapane. I lost him while I was in plant specimen identification at the National Herbarium (ETH), Addis Ababa University. No farewell words spoken, no time to say goodbye, you were gone before I knew it and only God knows why. So I pray to the almighty God for granting eternal peace and rest to the soul of my departed father.

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List of Acronyms

SPM	Strategic Planning and Management
EHRS	Ethiopian Highland Reclamation Study
EWNHS	Ethiopian Wildlife and Naural History Society
SNNP	Southern Nations and nationalities
GIS	Geographical Information System
CSA	Central Statistical Agency
RD	Relative Density
RF	Relative Frequency
DBH	Diameter at Breast Height
GPS	Geographical Positioning System
ETH	National Herbarium of Ethiopia
AWAO	Ambo Wereda Agricultural Office
IBC	Institute of Biodiversity Conservation
IUCN	International Union Convention of Nature and Natural Resources

CHAPTER ONE

INTRODUCTION

1.1. General Background

Plants are remarkably adaptive organisms, inhabiting such diverse environments as tropics and tundra, desert and ocean, mountains and marsh.Yet each species has an optimal habitat. There can be many reasons why a plant flourishes in one plot and not in another. For example, because of the differences in slope, or because of the sheltering effect of a large tree, plots just a few feet apart could be receiving very different amounts of water and light. The same conditions of slope or shelter can also be responsible for differences in temperature and wind velocity. Soil composition has a profound effect on plants. While many plants thrive in rich loam, only some specialized types can survive in sand or in compacted clay, and fewer still can find a foothold on rocky ledges. Each type of soil has a different capacity for retaining moisture, and each contains varying amounts of nutrients to give to the plant. Human activity plays a large part in determining plant abundance and diversity and has played a large part in planting it. (http://www.amnh.org/learn/biodiversity_counts/download/bc_08_chapter_4.pdf).

Ethiopia's vegetation reflects the great differences in the country's altitude. The lower areas of the tropical zone have sparse vegetation consisting of desert shrubs, thorn bushes, and coarse savannah grasses. The valleys and gorges are however densely covered in vegetation. The temperate zone is largely covered in grassland. Alpine vegetation is found on the highest areas of slopes, which turns into a desert-like rocky plateau above 3,900 m. (http://www.sos-childrensvillages.org/where-we-help/africa/ethiopia/pages/country-information.aspx)

According to Zerihun Woldu *et al.* (2002) and Zewge Teklehaimanot and Healey (2001), Ethiopia is endowed with rich fauna and flora because of its diverse ecological features, which make the country an important centre of diversity and endemism. Ethiopia is strategically located in the Horn of Africa, and has the requisite conditions for developing good quality tropical forests (Legesse Negash, 2010). Vegetation types with intermediate characteristics between savannahs and woodlands are shrublands and bushlands (Engeles and Hawkes, 1991). They also explained that shrublands are lands supporting a stand of shrubs, usually not exceeding 6 m in height, with a canopy cover greater than 20 percent. Trees are rare. The ground cover is often poor. Fires are usually infrequent whereas bushland is a vegetation cover supporting an assemblage of trees and shrubs, often dominated by plants with a shrubby habit but with trees always conspicuous, with a single or layered canopy, usually not exceeding 10 m in height and total canopy cover greater than 20 percent. Furthermore, it is characterized by poor ground cover and infrequent fires.

Seasonal distribution and amount of rainfall are crucial factors to vegetation development (Young and Giese, 1990). The most abundant species in an area therefore, are those of greatest physiological tolerance of the given range of conditions. Thus, richest stand could well reflect regions of more fertile soil, or operations of some factors such as grazing which improve the presence of additional herbs (Williams and Lambert, 1961). Therefore, the expected abundance of a given species in a given stand depends on the local climatic factors and other related factors in the stand (Palmer and Dixon, 1990; Lovett, 1993). In order to maintain the ecological equilibrium and to meet the forest resource requirements of the population, scientific information on the composition, structure and distribution of species is the basis for forestry development (Abate Ayalew, 2003). According to Kershaw (1973), the objective of vegetation description is to enable people build a mental picture of an area and its vegetation and to allow the comparison and ultimate classification of different units of vegetation. He also added about the necessity of vegetation description as it is essential to know what species are present, what their distribution is and what the relative degree of abundance of each species is before any serious or detailed work can be commenced in an area.

The natural environment is continually under threat from development, pollution, alien species invasions, and other human-related actions (Millennium Ecosystem Assessment 2005; cited in Brand *et al.*, 2009). The increasing pressures imposed by such actions threaten to lead to a loss of plant and animal species, which could lead to the degradation of an area. The prevention of large-scale loss of biodiversity is a daunting challenge facing the world today (Huntley, 1991;

cited in Brand *et al*., 2009).

Ethiopia, located in the Horn of Africa, is a largely mountainous country. The central highlands with altitudes between 1,500 and 4,000 m are dissected by numerous rivers, including the Blue Nile. The economy of Ethiopia is primarily based on agricultural production. Due to intensive land use and high population pressure, the land is severely degraded and eroded. In addition, the nutrient status of most soils is decreasing. Between 70 and 75% of the agricultural soils of the highland plateau area of Ethiopia are phosphorus deficient (Duffera and Robarge, 1999).

The depletion of the natural vegetation in many parts of the country has also led to the threat and decline in number and area of distribution of many plant species (Tesfaye Bekele, 2000). According to Ensermu Kelbessa *et.al.* (1992), 120 threatened endemic plant species are known from Ethiopia. Out of these, 35 species were from the Dry Afromentane Forest. The lack of conservation actions and activities is observed in the study area, which is similar to other areas in Ethiopia. As noted by Zerihun Woldu & Backeus (1991), the shrubland vegetation may have expanded from lower altitudes and drier sites as forests gradually disappeared. According to these authors, the recovery of an economically more rewarding vegetation type may be achieved through providing alternative sources of fuel and construction and through prohibiting cultivation and grazing in the shrublands on the hillsides.

1.2. Statement of the Problem

Misra (1974) noted that one of the essential and most important aspects of ecological investigation is the study of vegetation. Goldsmith & Harisson (1976) also stated that vegetation being an essential component of an ecosystem needs careful study and analysis since such study is used as a means of revealing useful information about vegetation of an area and ecosystem.The shrublands including the study area are made up of shrubs or short trees. Many shrubs thrive on flat, rocky slopes. There is usually not enough rain to support tall trees. Shrublands are usually fairly open so grasses and other short plants grow between the shrubs.

The study area is one of the areas where one finds high number of plant species diversity. This vegetation is highly valued for its high economic and ecological services. Despite these services, shrubland vegetation removal of this study area will apparently continue like the other parts of the country unless measure is taken (personal observation and communication with local inhabitants). Therefore, detailed biodiversity and ecological studies are desirable to draw the attention of policy makers to understand the ecosystem services of this biodiversity assemblage and undertake appropriate conservation measures. The loss of the vegetation cover on the central plateau including West Shewa due to the long history of sedentary agriculture has resulted in soil erosion. West Shewa, as part of the central highland has been faced with such challenge and the long time cultivation of crops from the same land without rest, and the highland steeply slopes are also among the factors that contributed to the sad situations that in return contributes to the climate changes symptoms of today. To reverse the condition, different stakeholders from grass root level to state, as well as internationally are expected to do their stake. Based on this background and baseline, this study was undertaken aiming at describing and providing available floristic information about shrubland vegetation of aroun Ambo, including some impacts on the vegetation of the study area. The information is supposed to be important for further studies, taking conservation measurements, formulating and implementing relevant policies, improving vegetation resources, etc.

1.3. Leading Questions

- ❖ What are the shrubs and other plant species found in the study area?
- ❖ What do the habits and habitat distribution of these plant species look like?
- ❖ What are the plant communities existing in the study area?
- ❖ What is the status of the shrubland in the study area?
- ❖ What are the vital problems facing vegetations in the study area?

1.4. Objectives of the Study

1.4.1 General objective

The general objective of the study was to:

- ❖ Identify and describe the plant communities and floristic composition of the vegetation between Ginchi and Ambo of West Shewa Zone of Oromia, central Ethiopia.

1.4.2 Specific objectives

The specific objectives of the study were:

- To identify the distribution, species richness, abundance and plant species of community types.
- To produce a species list for the area.
- To determine regeneration status of tree species.
- To obtain information that could provide some guidelines to implement sustainable management and for future research activities.
- To recommend solutions to the problem through management and conservation.

CHAPTER TWO

LITERATURE REVIEW

2.1 Vegetation Types and Their Broad-Scale Distribution

2.1.1 Vegetation concepts

Several scientific organizations have classified the world's vegetation to create a series of biomes, zones on Earth with shared characteristics which can be defined by the plant life they contain. There are a number of classification systems in use, depending on where in the world one is, which describe biomes in terms such as the types of plants found there, the soil conditions, the climate, and the historical use of the land. Some examples of vegetation biomes include tropical plants, high alpine plants, and desert plants (http://www.wisegeek.com/what-is-vegetation.htm).

Vegetation ecology, the study of the plant cover and its relationships with the environment, also called synecology, is a complex scientific undertaking, both regarding the overwhelming variation of its object of study in space and time, and its intricate interactions with abiotic and biotic factors. It is a comprehensive account of plant communities and their environments. It covers the composition, structure, ecology, diversity, distribution and dynamics of plant communities, with an emphasis on functional adaptations to the abiotic and biotic processes governing plant communities (http://www.ebooksdownloadfree.com/Science-Technology/Vegetation-Ecology-BI13317.html, 2009).

Vegetation can be defined in different ways according to different scientists: Vegetation is a general term for the plant life of a region; it refers to the ground cover provided by plants. It is a general term, without specific reference to particular taxa, life forms, structure, spatial extent, or any other specific botanical or geographic characteristics. It is broader than the term flora which refers exclusively to species composition. Perhaps the closest synonym is plant community, but vegetation can, and often does, refer to a wider range of spatial scales than that term does, including scales as large as the global. Primeval redwood forests, coastal mangrove stands, sphagnum bogs, desert soil crusts, roadside weed patches, wheat fields, cultivated gardens and lawns; all are encompassed by the term *vegetation*. (http://en.wikipedia.org/wiki/Vegetation) According to Box and Fujiwara (2005) vegetation, a term of popular origin, refers to the aggregate of all the plants found in an area and it involves the species (populations) of the local flora, which in turn involve different genetic, migration, historical or ecological elements. The vegetation of a region is also shaped by non-floristic physiological and environmental influences, including climate, substrate, soil microbes and disturbance regimes. The simplest concepts of vegetation types have been based on physiognomy, i.e. the general physical structure and appearance of the vegetation (Beard, 1973; cited in Box and Fujiwara, 2005). Vegetation types, though, are also often recognizable as and loosely equivalent to plant communities. Plant communities are also usually part of some larger ecosystem that involves the different populations of both plant and animal species that occur together at the particular site. It is the common experience of plant ecologists that vegetation is not a random assemblage of individuals of many species, but that plants are associated in communities, which have a definite structure and often a regular specific composition. Only the species, which are adapted to a particular habitat, are selected from the available propagules of the total flora of a region, and by mutual compatibility in requirements for nutrients and light (Poore, 1962).

A careful analysis of vegetation is a means of revealing important information about other components of the ecosystem (Goldsmith *et al*., 1986). Vegetation study could also help and promote selecting and employing the appropriate conservation and management plan for sustainable use of ecosystems (Kershaw, 1973). Floristic data are relevant for establishing the present situation for environmental impact assessment and for monitoring changes in ecosystem quality in terms of changing species composition. The structure and composition of vegetation is often a consequence of environmental gradients, which can be defined as a change in the value of a particular parameter, such as temperature, soil pH, soil moisture or species composition over space (Whittaker, 1975).

2.1.2. Plant community types

According to Austin (2005), a plant community can be broadly defined as (i) having a consistent floristic composition; (ii) having uniform physiognomy; (iii) occurring in a particular environment; and (iv) usually occurring at several locations. Plant communities are defined largely by species presence (or absence). Further formal description and classification of communities generally focus on features such as complete floristic composition, floristic structure and relative species abundances. Although others may first have suggested a formal methodology for such description and classification, the best known and most universally accepted methodology is the phytosociology of Braun-Blanquet (1965). This methodology requires complete inventory of all species composing the vegetation (full floristic inventory) and provides a simple, rapidly applicable method for describing the composition and three dimensional structure of vegetation in the field (Westhoff & van der Maarel, 1973).

Plant community according to Kent and Cooker (1992) can be defined as the collection of plant species growing together in a particular location that shows a definite association with each other. According to these authors, the species compositions of the communities better express their relationships to one another and environment than any other characteristics.

2.2 Sampling of Species Characteristics

According to Mareel (2005), the species composition of a plant community, the key element in its definition, is described in its simplest form by a list of species occurring in the sample plot. The following quantitative measures can be used to quantify the level that a species attains:

1. Abundance, the numbers of individuals on the sample plot. Abundance is the number of plant per unit area. Measurement of plant abundance requires the counting of individual plants by species in a given area. It can be used to show spatial distribution and ranges over time.

2. Frequency is the number of times a species occurs in subplots within the sample plot or within an undelimited phytocoenosis (formally plottless sampling). Frequency is the proportion of plots in which a species occurs. It is a measure of occurrence of a given species in a given area. It indicates how the species are dispersed and is an ecologically meaningful parameter. In

other words, it gives an approximate indication of the homogeneity of the stand under consideration (Kent and Coker, 1992). It gives an approximate indication for homogeneity and heterogeneity of vegetation. Lamprecht (1989) pointed out that high value in higher frequency and low value in lower frequency classes indicate constant or similar species composition. Conversely, high percentage of number of species in the lower frequency classes and low percentage of number of species in the higher frequency classes points out a higher degree of floristic heterogeneity (Simon Shibiru and Girma Balcha, 2004).

3. Cover can be measured species-wise; it is usually estimated along a cover scale. Many scales have been proposed (van der Maarel 1979), some of which are more or less linear (e.g. with 10% intervals), some geometrical.

4. Cover-abundance is a combined parameter of cover – in case the cover exceeds a certain level, e.g. 5% – and abundance. According to Digby and Kempton (1987), Sample abundance may often be assessed more rapidly with little effective loss of precision by visual estimation using a crude abundance score, say in a 1-9 scale.

2.3 Plant Cover Estimate

Cover is among the most widely used measures of abundance of plant species because it is not biased by the size or distribution of individuals. So, cover can be used to compare the abundances of species of widely different growth forms (Floyd and Anderson, 1987). Plant species cover is a popular variable for plant community description. In particular, vegetation cover most often is expressed as percentage of a two-dimensional soil surface area covered by a vertical projection of plants onto that surface (Greig-Smith, 1983; Bonham, 1989). Cover data usually are obtained by individual plant species and these data are summed to obtain total plant cover. However, if cover of individual species overlaps in a vertical position, a summation of cover by species overestimates total plant cover. Plant cover data have also been useful for ecological interpretation of changes in plant species composition associated with climatic fluctuations and with surface disturbances such as mineral extraction and livestock grazing.

As stated above, plant cover has been commonly defined as a percentage of ground area covered by plant parts. Comparisons of plant cover estimates obtained by any on-ground methods produce estimates that require visual examination by an observer. Despite its popularity and usefulness as a vegetation community descriptor, plant cover is often considered by ecologists to be a qualitative or semi-quantitative variable.

2.4 Diversity Indices

There are various indices or measures of alpha diversity that are used by ecologists, each of which have different kinds of information content (Schmitz, 2007). Diversity, which is synonymous with heterogeneity (Krebs, 1999), comprised species richness and evenness. Indices that combine both richness and evenness (heterogeneity) into a single value are diversity indices. Ecologists also use species diversity as one important measure of the structural heterogeneity of a community. There are many ways a community can be diverse in species. They may vary in number (richness) of species, degree of dominance by one or a few species, relative abundance of all species (evenness), number of rare species, number of nonnative species, vertical stratification of species, horizontal patchiness, number of growth or life forms, and so on (McIntosh, 1967). Whittaker (1975) distinguished three different kinds of species diversity along certain environmental gradient that he called alpha, beta and gamma diversity. Alpha diversity refers to the number of species within a sample area. Beta diversity describes the difference in species composition between two adjacent sample areas along a transect. Beta diversity is low when the overlap between the species composition of two quadrants is high, and is highest when the samples have no species in common at all. Gamma diversity describes regional differences in species composition (e.g., the difference in species composition between comparable habitats on two adjacent mountain ranges). In addition to this idea, Rosenzweig (1995) defined the above three terms as:

Alpha diversity (α) - refers to the diversity of species within a particular habitat or community.

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; Burley, 2001). Similarity index measures the degree to which the species composition of the quadrates/

samples is alike.

Ecologists have proposed other diversity indices that combine Species Richness with various weightings for relative abundance. The first kind of indices, called *heterogeneity* or *diversity* indices (Krebs, 1989 ; cited in Schmitz, 2007), quantify either the likelihood that two individuals sampled randomly from an area are not the same species (Simpson's index), or the likelihood that one cannot predict to which species the next individual collected in an area belongs (Shannon- Weiner index). In both cases, larger values of the indices imply more heterogeneity, and hence diversity, than do smaller values of the indices.

These two indices differ in their sensitivity to the weighting given to rare species.The Shannon-Weiner index is most sensitive to changes in the number of rare species sampled in an area whereas Simpson's index is most sensitive to changes in abundant species (Krebs, 1989; cited in Schmitz, 2007). Finally, ecologists have long known that natural communities have a few dominant species and many rare species and so wished to quantify such unequal representation.

2.4.1 Shannon Weiner diversity index

Shannon diversity index has emerged as the most widely used criterion to assess the conservation potential and ecological value of a site (Magurran, 1988). It is the most applicable index of diversity (Greig-Smith, 1981; cited in Abiyot Tilahun, 2009). Like Simpson's index, Shannon's index accounts for both abundance and evenness of species present. The proportion of species relative to the total number of species (pi) is calculated, and multiplied by the natural logarithm of this proportion (lnpi).

The Shannon diversity index (H') is calculated using the following formula,

$$H' = -\sum_{i=1}^{s} pi ln pi$$

Where, H'= Shannon Weiner diversity index**,** S=total number of species, Pi=the proportion of individuals or abundance of the i^{th} species as a proportion of total cover and ln=log base. Evenness: is a measure of the relative abundance of the different species making up the richness of an area. Evenness compares the similarity of the population size of each of the species**.**

According to (Mclean and Ivimer-cook, 1973; Kumar, 1981; Paul, 1993), species diversity can be viewed in terms of species richness (total number of species in a given area), species endemism (total number of species confined to that specific area), evenness (distribution or the relative abundance of the individuals within each species) and taxonomic diversity (measurements of magnitude of differences between species as seen by their taxonomic distribution in genera, orders, classes and Phyla). The two main techniques of measuring diversity are richness and evenness.

Richness: The most commonly employed diversity index is called Species Richness. It is a simple count of the number of species in an area. This index gives equal weighting to all species, whether they occur frequently and thereby dominate an area or they are rare. Because it does not account for commonness or rarity, Species Richness can be conflated by the contribution of rare species to the measure of species diversity. In many cases, we want to understand the richness of species relative to their relative abundance. 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; cited in Abiyot Tilahun, 2009). Species richness index has a great importance in assessing taxonomic, structural and ecological value of a given habitat. Richness *R* simply quantifies how many different types the dataset of interest contains. For example, species richness (usually notated *S*) of a dataset is the number of different species in the corresponding species list. Richness is a simple measure, so it has been a popular diversity index in ecology, where abundance data are often not available for the datasets of interest. Because richness does not take the abundances of the types into account, it is not the same thing as diversity, which does take abundances into account (http://en.wikipedia.org/wiki/Diversity_index).

For example, if there were four different subspecies observed in zone 1 and zone 2 the richness would be equal. This does not indicate what percentage of the abundance there were of each sub species. Species richness increases as a function of ecosystem size and appears to increase even within established communities, over time (Putman, 1994). Moreover, diversity is a function of time: all communities tend to diversify with time; therefore older communities will be to more species rich than young ones.

Evenness: 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. Species diversity indices provide information about species endemism, rarity and commonness (Muller-Dombois and Ellenberg, 1974). Evenness, according to Molinari (1989), is defined as the degree to which the abundances are equal among the species present in a sample or community and is a fundamental attribute of any multi species sample. To quantify evenness, as mentioned by this author, one must rely on an evenness index, which is a mathematical formula conceived to summarize evenness by assigning an evenness value to each sample. As is the case with other statistics, such as the mean, the median, the mode, and the standard deviation, evenness values are merely numbers: their relevance to an ecological problem must be judged by the ecologists on the basis of observed correlations with ecological or environmental variables of his or her interest. *Evenness* indices as Schmitz (2007) accomplish this by scaling the heterogeneity indices to a theoretical maximal value of diversity when all species are equally represented in the sample. In this case, large index values imply that the species are equally represented or equally abundant in a sample; small index values imply that there are a few species that are highly abundant and many that are rare. Ultimately, the choice of index to describe diversity depends largely on whether one is interested in emphasizing common species or rare species in an area.

2.4.2. Factors affecting species richness

According to Begon *et.al.* (2006), there are a number of factors to which the species richness of a community can be related, and these are of several different types.

2.4.2.1 Factors correlated with latitude

A second group of factors does indeed show a tendency to be correlated with latitude (or altitude or depth), but they are not perfectly correlated. To the extent that they are correlated at all, they may play a part in explaining latitudinal and other gradients. But because they are not perfectly correlated, they serve also to blur the relationships along these gradients. Such factors include climatic variability, the input of energy, the productivity of the environment, and possibly the ‘age’ of the environment and the ‘harshness’ of the environment. Zerihun Woldu *et al*., (1989) indicated that altitude is the main factor that orders the tree-shrub layer into respective vegetation types because it is positively correlated with some environmental factors like organic matter and negatively correlated with pH, clay and calcium.

2.4.2.2 Biotic factors

Finally, there is a group of factors that are biological attributes of a community, but are also important influences on the structure of the community of which they are part. Notable amongst these are the amount of predation or parasitism in a community, the amount of competition, the spatial or architectural heterogeneity generated by the organisms themselves and the successional status of a community. These should be thought of as ‘secondary’ factors in that they are themselves the consequences of influences outside the community. Nevertheless, they can all play powerful roles in the final shaping of community structure.

In general the distribution, abundance and diversity patterns of species can result from the interaction between biotic and abiotic factors at different spatial and temporal scales (Brown, 2001; Feyera Senbeta 2006). Variations in climate, temperature and rainfall distribution are generally reflected in the variations of the species composition and structure of communities (Brown, 2001; Grytnes and Vetaas, 2002).

2.5. Plant Resource Utilization

Wild naturalized plants give green social security to people of the world by providing low cost building material, fuel, food supplement, herbal medicine and basketry (Cunningham, 2001). The great importance of tropical forest product is ability of ensuring sustainability. According to Peters (1989; cited in Balik and Cox, 1996), a sustainable system for exploiting non-timber forest resources is one in which fruit, nuts, latexes and other products can be harvested indefinitely from limited area of forest with negligible impact on the structure and dynamics of the plant population being exploited.

2.6 Disturbance Effect

Management of plant communities and plant species should take into account the various natural and human-influenced processes. When applying management measures on a lower level one should be aware of the ecological processes occurring at a higher level beyond the influence of the local management. An Ethiopian Highland Reclamation Study (EHRS) conducted two decades ago revealed a frightening trend in environmental degradation where by "…27 million hectars or almost 50% of the highland area was significantly eroded, 14 million hectars seriously eroded and over 2 million hectare beyond reclamation.

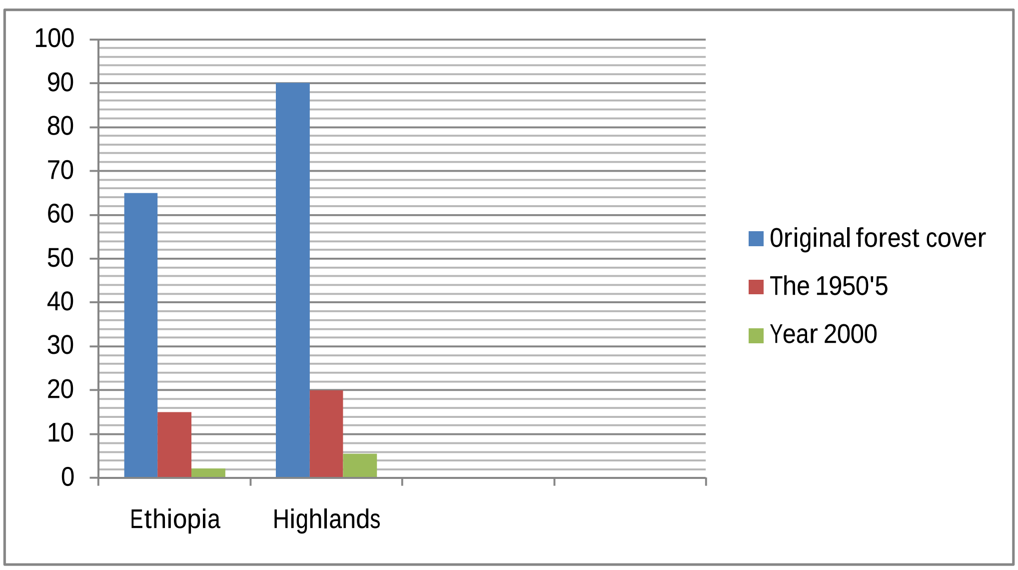

Figure 1: The Percentages of original forest cover and the coverage in 1950 and 2000 in Ethiopia

(Adapted from Aynalem Adugna: www.EthiodemographyAndHealth.orga)

As indicated in Figure 1, forests in general have shrunk from covering 65% of the country and 90% of the highlands to 2.2% and 5.6% respectively". With the country's population now almost double what it was then, things have, obviously, gotten much worse since (www.EthiodemographyAndHealth.Org). As a result, large areas, which were once under forest cover and natural pasture, are now exposed to heavy soil erosion resulting in a massive environmental degradation and posing a serious threat to sustainable agriculture. 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).

For animals, vegetation provides ample habitat along with food. Animals live in plants or use plant materials to construct homes, and many plants are edible, for at least some species. Other animals in turn prey on animals which feed on vegetation. Gardeners, whether they are growing food or ornamental plants, utilize plant life in a variety of creative ways, depending on the climate or zone they grow in. In areas where vegetation is lacking or scrubby, it can contribute to environmental problems. Loss of vegetation contributes to loss of topsoil, making the soil less useful, and it can also cause the area to grow warmer because the plants are not acting as a heat sink to keep temperatures more moderate. Lack of plants also means lack of food, a serious problem in regions of the world which are undergoing desertification and experiencing food insecurity as a result http://www.wisegeek.com/what-is-vegetation.htm.

2.7. Vegetation of Ethiopia

Owing to the diverse biophysical setting, Ethiopia hosts the fifth largest flora diversity in tropical Africa (EWNHS, 1996). It is estimated to consist of about 6,000 higher plant species, of which about 10 % are endemic (Ensermu Kelbessa, pers.comm). This results from the wide variations in climate, geology and terrain working on different time scales (EWNHS, 1996; Sebsebe Demissew *et al.*, 2003). It has very diverse climatic conditions varying from hot and dry desert in the lowland areas to cold and humid alpine habitats in the highlands.

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; cited in Birhanu Kebede, 2010). Furthermore, the vegetation is extremely complex due to great variations in altitude implying equally great differences in moisture regimes as well as temperatures within very short horizontal distances (Zerihun, 1999).

Vegetation in Ethiopia is comprised of four main biomes, which are found across the country's regions. The first biome is savanna, consisting of montane tropical vegetation with dense forests and rich undergrowth and drier savanna and tropical dry forests mixed with grassland at lower elevations of the Western and Eastern Highlands. The second biome is comprised of mountain vegetation, mostly montane and temperate grasslands, covering the higher altitudes of the Western and Eastern Highlands. The third biome is made up of tropical thickets and wooded steppe, and is found in the Rift Valley and Eastern Lowlands. The fourth biome is desert steppe vegetation, covering areas of the Denakil Plain.

(http://earthobservatory.nasa.gov/Experiments/Biome/bioshrubland.php)

According to the work of many scholars, the vegetation of Ethiopia is classified into eight major types (Ensermu Kelebessa *et al.*, 1992; Zerihun Woldu, 1999; Friss, I. & Sebsebe Demissew, 2001; Sebsebe Demissew *et al*., 2003). The summerized description and distribution of these major vegetation types Compiled from Ensermu Kelbessa *et al.*, 1992; Zerihun Woldu, 1999; Sebsebe Demissew *et al.*, 2003 and Institute of Biodiversity Conservation (IBC), 2005 is indicated below.

1. Afroalpine and Sub-Afroalpine

The ecosystem includes areas, which on the average are higher than 3200 m. The subafroalpine areas occur between 3200 and 3500 m, while the afroalpine areas occur between 3500 m and 4620 m. The ecosystem is characterised by the most conspicuous giant Lobelia, *Lobelia rhynchopetalum*, and evergreen shrubs including the heather, *Erica arborea* and perennial herbs such as *Helichrysum* species.

2. Dry Evergreen Montane Forest and Grassland Complex

This ecosystem represents a complex system of successions involving extensive grasslands rich in legumes, shrubs and small to large-sized trees to closed forest with a canopy of several strata occurring between (1600-) 1900-3300 m. This ecosystem covers much of highland areas and mountainous chains of Ethiopia.The areas with Dry Evergreen Afromontane forest have canopies usually dominated by Tid/Gatira (*Juniperus procera)* as a dominant species, followed by Weira/Ejersa (*Olea europaea* subsp. *cuspidata*), etc. Zigba/Birbirsa (*Podocarpus falcatus)* is also found in sheltered valleys. The areas with Afromontane woodland, wooded grassland and grassland include the natural woodlands and wooded grasslands of the plateau with *Acacia abyssinica* and *A. negrii.*

3. Moist Evergreen Montane Forest

This ecosystem is in most cases characterised by one or more closed strata of evergreen trees, which may reach a height of 30 to 40 m. The vegetation type in this ecosystem can be further divided into two (Friis, 1992; Sebsebe Demissew *et al*., 2004). One type includes what is traditionally referred as the Afro-montane rainforest. These forests occur in the southwestern part of the Ethiopian Highlands between 1500 and 2600 m elevation and the Harenna Forest on the southern slopes of the Bale Mountains. The forests characteristically contain a mixture of Zigba (*Podocarpus falcatus*) and broadleaved species as emergent trees in the canopy including Kerero (*Pouteria (Aningeria) adolfi-friederici*). Kerkha (the mountain bamboo- *Arundinaria alpina*) is also one of the characteristic species, although not uncommon is found locally. There are also a number of medium-sized trees, and large shrubs. The second type includes the Transitional Rainforest, which includes forests known from the western escarpment of the Ethiopian Highlands, in Wellega, Illubabor and Kefa. The forest type occurs between 500 and 1500 m elevation. The characteristic species in the canopy includes *Pouteria (Aningeria) altissima, Anthocleista schweinfurthii, Ficus mucuso* and species of *Garcinia, Manilkara* and *Trilepisium.*

4. Acacia-Commiphora Woodland

This ecosystem is characterised by drought resistant trees and shrubs, either deciduous or with small, evergreen leaves occurring between 900 and 1900 m. This vegetation type occurs in the northern, eastern, central and southern part of the country mainly in Oromia, Afar, Harari, Somali, and Southern Nations Nationalities and Peoples Regional States.

The trees and shrubs form an almost complete stratum and include species of Grar/Lafto (*Acacia senegal, A. seyal, A. tortilis*), Bedeno (*Balanites aegyptiaca*), and Kerbe (*Commiphora africana, C. boranensis, C. cilliata, C. monoica and C. serrulata*). The ground cover is rich in sub-shrubs, including species of *Acalypha, Barleria, Aerva*, and succulents with a number of Ret/Argessa (*Aloe*) species.

5. Combretum-Terminalia Woodland

This ecosystem is characterised by small to moderate-sized trees with fairly large deciduous leaves. These include Yetan Zaf (*Boswellia papyrifera*), *Anogeissus leiocarpa* and *Stereospermum kunthianum* and species of Weyba (*Terminalia*), *Combretum* and *Lannea*. The solid-stemmed lowland bamboo, Shimel (*Oxytenanthera abyssinica*) is prominent in river valleys [and locally on the escarpment] of western Ethiopia. The vegetation type occurs along the western escarpment of the Ethiopian Plateau, from the border region between Ethiopia and Eritrea to western Kefa and the Omo Zone (in the SNNP Region); it is the dominant vegetation in Benshangul-Gumuz and Gambella Regions, and the Dedessa Valley in Wellega in Oromia Region, where it occurs between 500 and 1900 m. The vegetation in this ecosystem has developed under the influence of fire. The soil erosion rate is very high especially at the onset of rains.

6. Lowland Semi-evergreen Forest

This ecosystem includes forests that are restricted to the Lowlands of eastern Gambella Region in Abobo and Gog Weredas. They occur between 450 and 650 m on sandy soils.
They are semi-deciduous, with a 15-20 m tall, more or less continuous canopy in which *Baphia abyssinica* is dominant, mixed with less common species including *Celtis toka, Diospyros abyssinica, Malacantha alnifolia*, and *Zanha golungensis* and species of *Lecaniodiscus, Trichilia* and *Zanthoxylum*.

7. Desert and Semi-Desert Scrubland

This ecosystem is characterised by highly drought tolerant species of Grar/Lafto (*Acacia brichettiana, A. stuhlmanii* and *A. walawlensis*), Etan (*Boswellia ogadenenesis*) Kerbe (*Commiphora longipedicillata* and *C. staphyleifolia),* as well as succulents, including species of *Euphorbia* and *Aloe.* The doum palm (*Hyphaene thebaica*), grasses such as *Dactyloctenium aegyptim* and *Panicum turgidum* are also characteristic species.

8. Riparian and swamp vegetation

This ecosystem consists of both running (lotic) and standing (lentic) inland water bodies, including rivers, lakes, reservoirs, swamps, wetlands and aquatic bodies with transient water contents during some time of the year. Although the floristic composition of the riverine vegetation varies depending on altitude and geographical location, in general it is mainly characterised by species of *Celtis africana*, *Mimusops kummel*, *Tamarindus indica*, etc. The swamps, reservoirs and shores of lakes are dominated by species of sedges and grasses.

These diverse ecosystems, according to the institute of biodiversity conservation of Ethiopia (2005), have endowed Ethiopia with a diverse biological wealth of plants, animals, and microbial species. However, the attention given to the conservation and sustainable use of these biological resources has been inadequate. Some of the major contributory factors to accelerated decline of the biological resources are the size and pattern of the distribution of human and animal population, the level of resource consumption, market factors and policies. Under-valuation of environmental resources due to low-level of awareness about the role of ecosystems and the rate at which it is being deteriorated or lost and poor regard to the conservation problems have also contributed to under-investment in biological resources management.

2.8 Plant Population Structure

Population structure is defined as the distribution of individuals of each species in arbitrarily diameter-height size classes to provide the overall regeneration profile of the study species (Peters, 1996; Simon Shibru and Girma Balcha, 2004).

Forest ecologists use the frequency distribution of DBH (diameter at breast height, 1.35 m above ground) of the stems of woody species to describe age/size structures and draw inferences about regeneration strategies, synchrony of climatic events, mortality patterns and the effects of animal browsing (Allen *et al*., 1984). Information on population structure helps to respect the healthy regeneration of the species under utilization (Kindeya G/Hiwot, 2003).

Diameter at breast height (DBH) is one of the most common dendrometric measurements and a standard method of expressing the diameter of the trunk of a standing tree. The two most common instruments used to measure DBH are a girthing (or diameter) tape and calipers. A girthing tape actually measures the girth (circumference) of the tree; the girthing tape is calibrated in divisions of π centimetres (3.14159 cm), thus giving a directly converted reading of the diameter. This assumes the trunk has a circular cross-section, which is typically accurate for most plantation trees. Calipers consist of two parallel arms one of which is fixed and the other able to slide along a scale. Calipers are held at right-angles to the trunk with the arms on either side of the trunk (http://en.wikipedia.org/wiki/Diameter_at_breast_height).

DBH is used in estimating the amount of timber volume in a single tree or stand of trees utilising the allometric correlation between stem diameter, tree height and timber volume, (Mackie, 2006). In more complex vegetation the height frequency distribution, or profile, of the community as a whole may show several distinct modes**;** for example, those corresponding with the upper limits of herb, shrub and tree strata in a forest community (http://www.nzes.org.nz/nzje/free_issues/ProNZES17_1.pdf).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Study location and characteristics

The study sites, namely Awaro Kora Kebele (Tulu Facha Shrubland), Senkele Faris Kebele (Senkele & Teltele Shrubland), Gosu Kora Kebele (Tulu Miessa Shrubland) and Kisose Ido Liban Kebele (Wadessa Shrubland) are located in the study area of West Shewa Zone of Oromia Region. The West Shewa Zone is endowed with a high potential for agriculture. Ambo is located 112 kms West of the capital Addis Ababa, on the road to Nekemt and popular for its immense natural gifts including excellent climate which provides comfortable living and working environment. The town is also famous for its mineral water which is bottled outside of town and widely consumed all over the world. (http://maps.thefullwiki.org/Ambo, Ethiopia). Ambo lies at latitude of 8^0 59'N and longitude of 37^0 51E at an elevation of 2101 m (6893ft) and the District covers a total area of about 83,598.69 hectares (Office of Agricultural & Rural development of Ambo District- 2002 SPM Information). The study area District lies approximately between latitudes 8^0 54` and $8^0$59` North and longitudes 37^0 48` and $38^0$02` East.

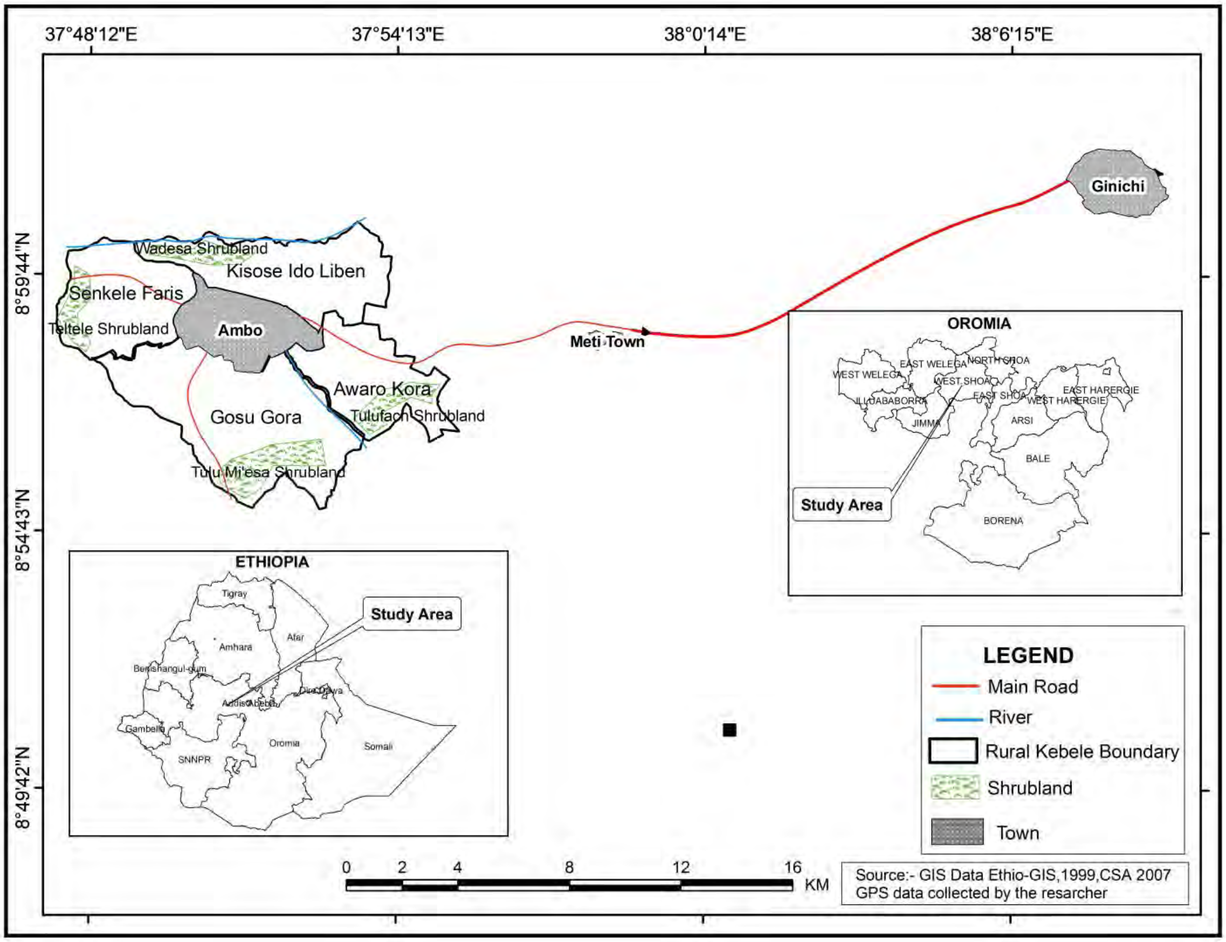

Figure 2: Map of Ethiopia and West Shewa Zone showing study area (Source: Adapted from GIS Data Ethio-GIS,1999, CSA 2007)

3.1.2 Topography

The study area has diverse topography and this diversity of landscape contributes to the slight variation of natural vegetation by determining local variations in climate and soil composition (personal observation). Tullu Facha is estimated to be 15 km away from Ambo town in the eastern direction. It has a moderate slope and the land has been cultivated for vegetables with some grass-covered areas mainly used for the grazing of cattle. Senkele, which is about 6 km west of Ambo, has a gentle slope and the land has been used for only three years for the cultivation of maize whereas Tullu Miessa shrubland (Gosu Kora Kebele) is estimated to be 10 km away from Ambo town in the southern direction. It has a moderate slope and has been cultivated continuously for 11 years for teff and wheat (Attah, 2010).

Figure 3: Senkele Faris area(a) and Tulu Miessa area shrublands(b) : Photo taken by Belete Kebede

3.1.3 Climate of the area

According to Southwick (1996), climate is a function primarily of latitude, altitude, and topography. He also stated that climates and seasons reflect long-term weather patterns. These patterns result from solar radiation, day length, temperature regimes, precipitation, cloud cover, and wind factors that contribute to tropical, temperate, or cold climatic regimes. Despite its proximity to the equator, Ambo enjoys a mild, Afro-Alpine temperate and warm temperate climate (Prabu *et al*., 2010). The agroclimate of Ambo District is Kola (14.7%), Weina Dega (50%), and Dega (35.3%) **(**Office of Agricultural & Rural development of Ambo District- 2002 SPM).

Meteorological data of monthly maximum and minimum temperature and monthly rainfall were taken from Ambo station for the period 1997 to 2009. Analysis of the meteorological data result showed that the mean annual temperature of the study area is about 20.1^{0}C, ranging from a mean minimum of 10.3 ^{0}C to mean maximum of 29.8 ^{0}C. The mean annual rainfall of the area is 1129 mm year -1. The lowest mean temperature over thirteen years was 10.3 ºC recorded in November, whereas the highest was 29.8 ºC recorded in March.

Meteorological data of Ambo station obtained from National Meteorology Agency (Addis Ababa) indicates that the study area obtains high rainfall between May and September and low rainfall from November to February (Figure 3). The rainfall pattern of the area is unimodal (Dereje Bacha *et al.*, 2009) and over 58.9% of the total annual rainfall is received in just three months, namely June, July and August.The highest mean monthly rainfall of the study area within thirteen years (1997 - 2009) was 206.6 mm recorded in August followed by 204.8 mm in July whereas the lowest mean annual rainfall was 6.5 mm recorded in December.

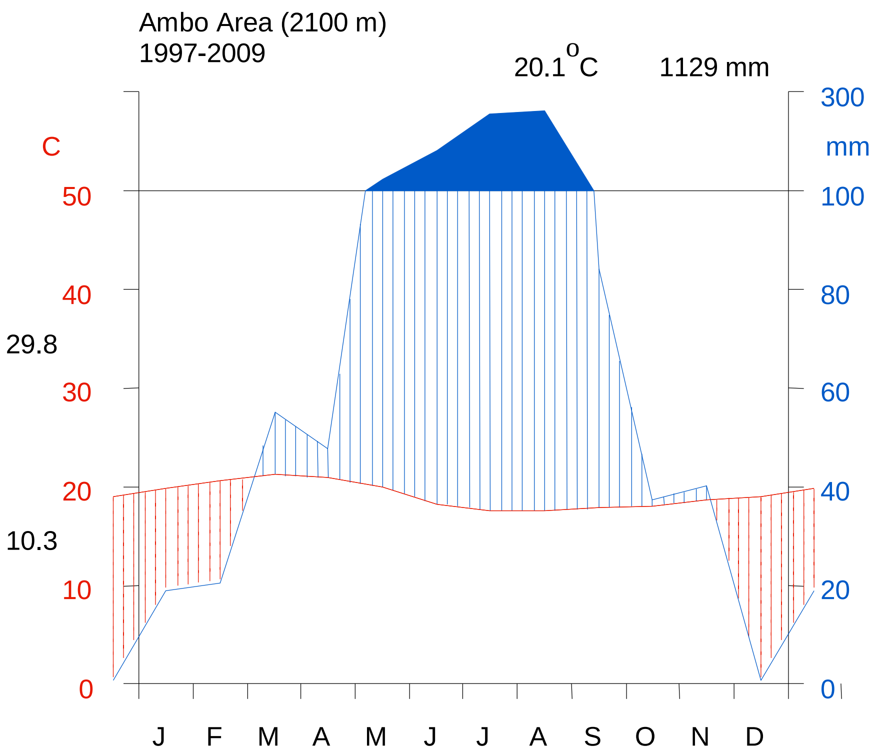

Figure 4: Climate diagram showing rainfall distribution and temperature variation from 1997-2009 at Ambo Station. Source**:** Data obtained from National Meteorological Agency, 2011/12.

3.1.4 Demographics and land uses

According to the Central Statistical Agency (2007), Ambo District has a total population of 110,796 of whom 55,305 are males and 55,491 are females. Crop and livestock production forms the main livelihood strategy for the majority of the population of the study area. Both annual and perennial crops, including cereals, pulses, oil crops, vegetables and root crops are grown in the District. Cereals comprise the largest proportion of the cropped area. According to the information from Department of Agriculture and Rural Development of Ambo District and Dereje Bacha *et al*. (2009), the major livestock reared include cattle, pack animals such as mules, horses and donkeys; small ruminants such as sheep and goats; and poultry. Uses of plough, crop rotation, terracing, irrigation and soil fertilization have been practiced by the farmers for more than 3000 years as part of their traditional farming system (Teshome Hunduma, 2006). Mixed agriculture in which livestock are used as a source of draft, transportation and animal produce is practiced in the District. Environmental degradation, charcoal making, collection of fuel wood, construction materials and the need for agricultural land resulted in major threat to the vegetation of the area. In support to this idea, Mponela *et al*. (2010) pointed out that conservation of plant species within patches of marginal and degraded areas has been considered to be a step towards revising the decrease of biodiversity due to increasing demand for agricultural land and intensified farming. In support to this idea, Brand *et al.* (2009) stated that the natural environment is constantly under threat from human-related activities.

Figure 5: Vegetation threatened by human activities (Photo taken by Belete Kebede)

Table 1 : Major food crops grown in the study area

No	Crop category	Scientific name	English name	Local name (Oro.)
1	Cereals	*Sorghum bicolor*.L.	Sorghum	Boobee
		Zea mays L.	Maize	Boqqolloo
		Eragrostis tef (Zucc.)Troteer	Tef	Xaafii
		Eleusine coracana (L.)Gaertn	Finger millet	Daagujjaa
		Hordeum vulgare L.	Barley	Garbuu
		Triticum aestivum L	Wheat	Qamadii
2	Fruits	*Citrus sinensis* (L.)Osb	Citrus	Burtukaana
		Citrus aurantifolia	Lime	Loomii
3	Pulses	*Pisum satium* L.	Field peas	Atara
		Phaseolus vulgaris L.	Haricot bean	Adenguare
		Vicia faba L.	Horse bean	Baaqelaa
4	Cash crops	*Nicotiana tabacum* L.	Tobacco	Tamboo
5	Oil crops	*Linum usitatissimum* L	Lin seed	Talbaa
		*Guizoia abyssinica(*L.f.)	Niger seed	Nuugii
		Brassica napus L.	Rape seed	Sanyii raafuu
6	Vegetables	*Capsicum frutescens* L.	Pepper	Barbaree
		Allium cepa L.	Shallot	Qullubbii
		Lycopersicon esculentum Mill.	Tomato	Timatimii
		Cucurbita pepo L.	Pumpkin	Buqqee
		Allium sativum L.	Garlic	Qullubbii adii
		Brassica oleracea L	Cabbage	Raafuu
7	Root crop	*Ipomoea batatas* (L) Lam.	Sweet potato	Qocho-biree

Source: Ambo Wereda Agricultural Office (AWAO, 2002)

3.1.5 Vegetation

The study area is characterized by shrublands which are made up of shrubs or small trees and are usually fairly open; grasses and other small plants grow between the shrubs (personal observation). Vegetation is patchy and compossed of small to medium sized shrub species dominated with some scattered tree species. The vegetation description presented by Zerihun Woldu and Backéus (1991) shows that the study area is characterized by dry evergreen montane forest on the basis that the dry evergreen montane forest covered the area between 1500 and 3000 m a.s.l. in the central and northern part of the country. Dry Evergreen Montane Forest is a very complex vegetation type occurring in an altitudinal range of 1500-2700 m, with average annual temperature and rainfall of 14-25° C and 700-1100 mm, respectively (Friis, 1992). The Ethiopian highlands contribute more than 50 % of the land area of Ethiopia with Afromontane vegetation, of which dry montane forests form the largest part (Tamrat Bekele, 1994).

The common plant species of the study area include *Olea europaea* subsp. *cuspidata*, *Albizia schimperiana, Acacia* spp., *Carissa spinarum, Cordia africana, Olinia rochetiana,Croton macrostachyus,Ptrerolobium* spp.,*Maytenus arbitifolia, Clausena anisata, Osyris quadripartita, Maesa lanceolata, Vernonia* spp., *Ficus* spp, *Phoenix reclinata, Premna schimperi* , *Myrsine africana, Bersama abyssinica, Calpurnia aurea* and different shrubs and herb species. In line with this, Zerihun Woldu and Backeus (1991) stated that the whole shrubland is characterized by *Carissa spinarum, Maytenus arbutifolia, Myrsine africana* and *Olea europaea*. Evenif the area is well known by natural vegetation, there are also few plantations of Eucalyptus spp. and Grevillea spp. particularly in Tulu Miessa shrubland site.

3.1.6 Soils

The physical and chemical composition of soils is very important in determining the occurrence, growth, diversity and distribution of plant species. According to Attah (2010), the soils around Awaro, Senkele and Meja (toward Gosu Kora) are dominated by clay along with course particles of sand (Table 2). Bulk density, organic carbon and electrical conductivity are low in the soil samples and the soils are acidic. The soil around Ginchi is a heavy clay with

0.91-32% organic matter, 0.09-0.14% N and 4.2-9.9 ppm available P (Morton, 1977); the pH is about 6.4 (Hailu Kenno and Lulseged Gebre Hiwet, 1983).

According to Office of Agricultural & Rural development of Ambo District- 2002 (SPM Information), the District has different soil types, which include:

Clay soil (Biyyoo diimillee**) –** a soil having red color and poor fertility. On this soil, people cultivate crops like *Ipomoea batatas, Capsicum frutescens* and *Cucurbita pepo.* About 36.25% of the district is characterized by this type of soil.

Black soil (Biyyoo kootichaa**) -** a soil with better fertility than other soil types. Crops like *Pisum satium, Vicia faba, Allium cepa, Zea mays, Eragrostis tef, Phaseolus vulgari*s and *Linum usitatisimum, Guizoita abyssinica and Brassica napus* are cultivated on such soil.

Sandy soil (Biyyoo Cirrachaa**) -** sandy soils and silt soils resulting from deposition by erosion. This soil type is suitable to grow specific crop types.

Mixed soil type (Biyyoo Makaa**) –** meaning soil type characterized by containing all the above three soil types.

Table 2: Physicochemical properties of rhizosphere soils of Ambo District which are in the study site. (Adapted from: Attah, 2010)

Soil property	Awaro	Senkele	Meja (near Gosu Gora)
Sand (%)	34.2 ± 0.05	32.4 ± 0.02	30.7 ± 0.06
Silt (%)	26.5 ± 0.02	24.6 ± 0.04	28.6 ± 0.04
Clay (%)	40.4 ± 0.05	44.5 ± 0.05	43.7 ± 0.02
pH	6.2 ± 0.04	6.4 ± 0.05	6.7 ± 0.02
Textural class	Clay loam	Clay loam	Red clay loam

3.1.7 Topographic land classification

According to the District Agricultural Office, the area can be described topographically as follows:

Dirree - refers to an extensive area that is not suitable for agriculture in most cases. It is left aside by the community for common grazing and browsing. It is an open grazing land containing shrubs, herbs and bushes as observed in the study area.

Tullu (26%) - mountain area characterized with higher altitude and covered with vegetations.
Hallayyaa (15%) -land forms with smaller elevation (hills) compared to Tullu.
Bu'aa ba'ii (18%) - irregular topography.
Lafa ciisaa (38%) - plain on which settlement where agricultural activities are usually practiced.

3.2 Methods

3.2.1 Vegetation data collection and identification

3. 2. 1. 1 Reconnaissance survey

A reconnaissance survey of the study area was conducted from 20-29 September 2011 and determined to include all the existing patches found around Ambo which were five in number. The study area is found within the range of 2002-2554 m a. s. l. The survey was made in order to obtain the general vegetation patterns of the study area, to collect some base line information on accessibility and to identify sampling design. Thus the study was carried out in a slightly altitudinally varying five sites. The actual fieldwork was undertaken from 2 October 2011 to 30 October 2011 on two field trips made to the sites. Field observation was performed with the help of local guides to collect plant specimens and to get the exact local names of the plants in the study area.

3.2.1.2 Sampling design and data gathering techniques

Vegetation data were collected from sample plots of five sample sites (patches) found around Ambo. These study sites were selected by preferential sampling technique by considering the amount of vegetation each site holds. Too small patches were omitted. Quadrats of 20 m x 20 m (400 m^2) were laid systematically at every 20 meters interval following smaller elevation (up the hill). The number of plots was determined proportional to patch size and a total of 52 quadrats were laid out based on their size. Details of quadrats per site are presented in Table 3 below. Sample quadrats of the first two patches (Table 3) which is relatively large in size were determined after the total area of the patch is estimated and then $1/3^{rd}$ of the total patch area was taken to lay quadrats which could be expected to represent the whole patch .On the other hand, the size of the remaining patches (sites) was not large so that the whole area was considered to lay quadrats. The starting point of quadrat was determined randomly.

Table 3. Sites of the study area with their plot size

Patches (Sites)	Direction	No. of quadrats
Tulu Facha shrubland	East of Ambo town	17
Tulu Miessa shrubland	South of Ambo Town	15
Senkele Faris shrubland	West of Ambo town	5
Teltele shrubland	North-west of Ambo town	8
Wadessa shrubland	North of Ambo town	7
Total		52

Within the main quadrat, five $1m^2$ (1m x1m) subquadrats; four at each corners and one at the center (Figure 6) were laid to record herbaceous plants. Cover abundance of each herbaceous species was estimated visually which were encountered in each subplots placed at the four corners and the center of the main plot. Afterwards, the total cover of a species in five subplots was divided by the number of subplots (5) and the result was converted to cover abundance value of Braun-Blanquat scales. So that, the same method was applied for all herbaceous species of the study area. All woody & herbaceous plant species were recorded and visual estimates of percent cover for each woody plant were recorded using the 400 m^2 plot. Percentage cover was estimated as a vertical projection onto the ground of all above ground parts of the individual plant species.

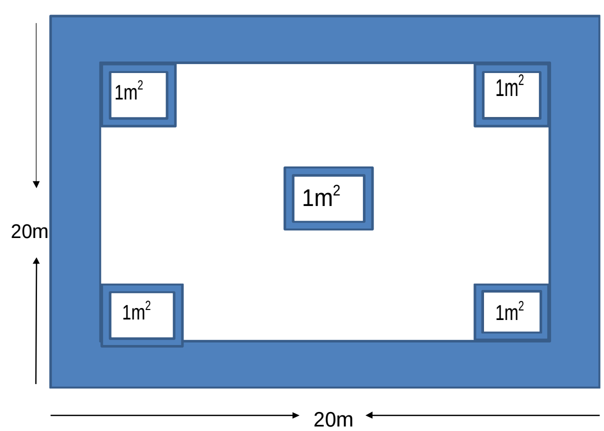

Figure 6: Layout of the study quadrat of all patches of the study area.

3.2.1.3 Floristic data collection

All plant species including herbs, shrubs, lianas, epiphytes, ferns and trees in each quadrate were recorded. The vernacular (local) names were used when available. In the study area, physiographic variables such as altitude and geographical coordinates were measured for each quadrat using Garmin GPS 60.

3.2.1.4 Plant specimen identification

Plant specimens were collected, numbered, pressed, and dried for identification. Local people were involved in species identification using local names and the corresponding scientific names were checked in the National Herbarium (ETH) of Addis Ababa University and identified between November and December 2011, by comparison with authenticated specimens, illustrations and with the assistance of advisor and finally deposited there with their labels after confirmation by Prof. Ensermu Kelbessa, one of my two advisors.

3. 2. 1. 5 Structural data collection

The number, height, DBH (diameter at breast height) >2cm were documented for each tree individuals in the plots. Each individual of woody species was counted, their circumference was measured and the height of each tree above 2 m was taken. Percentage cover of trees, shrubs and herbs were estimated in the field by visual observation and latter converted to cover/abundance values of Braun-Blanquet scales as modified by van der Maarel (1979). This new cover-abundance scale is an effective, easy to use directly in the field and the raw data can be easily entered into the data-processing system for vegetation community classification. Accordingly, the scale represents:

1 = rare, generally one individual,

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

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

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

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

6 = 12.5 -25% cover of total area,

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

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

9 = 75-100% cover of the total area

3.2.2 Vegetation data analysis

All individuals of species recorded in all the 52 quadrats were used in the vegetation data analysis. The vegetation classification was made using cover abundance values. Vegetation data for each plant species which were originally estimated and recorded in the form of percent cover values were converted into cover/ abundance values of Braun Blanquet (1965) Scales modified by van der Maarel (1979). In addition, a floristic approach of Braun-Blanquet scale was to determine the relative cover proportion of individual species for each of the community types.

The percent cover of 110 plant species (both herbaceous and woody) from the fifty two sample plots were classified by the agglomerative hierarchical classification using similarity ratio. Consequently, a hierarchical cluster analysis (classification) was performed to classify the vegetation into plant community types. A traditional table analysis was also computed. Abundance data of the species were used for cluster analysis as input. The community types distinguished were further refined in a synoptic table where each column represents a community type and species occurrences were summarized by synoptic cover-abundance values. Synoptic cover-abundance value was calculated as mean cover-abundance value for each species (Kent and Coker, 1992). These synoptic values are the products of the species' frequency and average cover-abundance values (Van der Maarel *et al.*, 1987). Community types were named after diagnostic species are selected and finally results were presented using tables, charts and graphs. A diagnostic species in this case is a species having a high synoptic cover-abundance value (mean frequency x mean cover-abundance) in the type and a lower frequency in most other types.

3.2.2.1 Plant community analysis

Plant community data consist of lists of species in each sample or records of the amount of each species in each sample, forming a two-way table or matrix with “n” rows and “m” columns. This complete data set cannot be easily interpreted unless summarized retaining the information in inter-unit relationships (Anderson, 1971). Thus, multivariate techniques (Hierarchical cluster analysis or classification) are employed to study the complex nature of plant communities, with the general objectives of summarizing large complex data sets obtained from community samples, aiding in the interpretation of the data and the generation of hypothesis about community structure and variation (Lambert and Dale, 1964 ; Greig-Smith, 1964). Among these multivariate methods employed to study the complex nature of communities, classificatory techniques were employed to analyze the vegetation data of shrubland vegetation around Ambo. Classification involves the arrangement of samples into classes the members of which have one or more common characteristics, which can distinguish them from the members of other classes.

3.2.2.2 Plant diversity analysis

Species richness, evenness and diversity were measured using Shannon and Wiener (1949) diversity index. Shannon Wiener diversity index, species richness and Shannon’s evenness were computed to describe species diversity of the plant community types in the vegetation. Species diversity is a characteristic unique to the community level of biological organization. Higher species diversity is generally thought to indicate a more complex and healthier community because a greater variety of species allows for more species interactions, hence greater system stability, and indicates good environmental conditions. A community is said to have high species diversity if many nearly equally abundant species are present. If a community has only a few species or if only a few species are very abundant, then species diversity is low (Brower *et al*. 1984; cited in Shiferaw Belachew, 2010).

3.2.2.3 Structural data analysis

For structural data analysis of plant species: species densities, height, and diameter at breast height (DBH) were used for description of vegetation structure. All individuals of trees with a DBH greater than 2 cm, and height greater than 2 m were measured for DBH. Species composition and size class indicate the likely state of the vegetation of a site (Enright, 1982). The purpose of using size class distributions in DBH is used to investigate the regeneration status of the woody plant species (Peters, 1996).

Accordingly, DBH, which was measured using ordinary measuring meter tape and calculated by dividing the circumference of the woody species, measured at about 1.3 m heights above the soil surface by π following Martin (1995).

Circumference (C) = πd, where d is diameter at breast height and $\pi = 3.14$.

For tree species having more than one branch (at or below breast height), DBH was measured separately for each branch and averaged. Tree density was computed on hectare basis. The population structure was analyzed using histograms with the grouped diameter classes following Mekuria Argaw *et al*. (1999). The vegetation data of the species were calculated and summarized on Excel spreadsheet using the following formulas.

Density**:** the number of individuals of size class in the stand is important to characterize vegetation. Density is determined by counting the number of individuals of each size class of each sample plot. It is closely related to abundance but more useful in estimating the importance of a species. Tree density was computed by converting the count from the total quadrats in the hectare basis (Table 8).

$$\text{Density} = \frac{\text{Total No.of stems of all trees}}{\text{sample size in hectare}}$$

$$\text{Relative density (RD)} = \frac{\text{No. of individuals of tree species}}{\text{Total No. of individuals}} X100$$

In the study area, counting was usually done in the 52 quadrats under study. Then after, the sum of individuals per species is calculated in terms of species density per hectare.

Frequency: The frequency of quadrats occupied by a given species. It is the chance of finding a species in a particular area in particular trial samples. The value obtained reflects the pattern of distribution and species diversity. It is calculated with the formula:

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

The frequencies of all species in all the 52 plots were computed (Appendix 4).The frequencies of the tree species with DBH greater than 2 cm in all the 52 plots were also computed in a separate spreadsheet. The higher the frequency, the more important the plant is in the community. A better idea of the importance of a species with the frequency can be obtained by comparing the frequency of occurrences of all of the tree species present. The result is called the relative frequency and is given by the formula:

$$\text{Relative frequency(RF)} = \frac{\text{frequency of a species}}{\text{sum of frequencyof all species}} \text{ X } 100$$

DBH (Diameter at Breast Height**):** DBH is the most frequent measured variable in vegetation surveys and has multiple uses. Over bark diameter measurements at breast height (1.3 m from the ground) are quick, easy, inexpensive, relatively accurate and usually correlated with other variables such as basal area i.e, the horizontal or cross-sectional area occupied by the trunk of a species or size class (Abate zewudie, 2007).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Floristic Composition

A total of 110 plant species representing 98 genera and 48 families were recorded (Appendix 1). The major families were Asteraceae represented by 16 species (14.5%), Fabaceae by 13 species (11.8%), Poaceae by 8 species (7%), Lamiaceae by 7 species (6.4%), and Rubiaceae by 5 species (4.5%) (Table 3). See a complete list in the Appendix. The rest of the families were represented by one to four species. Most of the recorded families belonged to angiosperms except two families namely, Dennstaedtiacceae (fern) and Cupressaceae (gymnosperm). From all the species collected 32.73% were herbs, 18.2 % trees, 4.6 % trees/shrubs and 39.1% were shrubs.

Table 4: The top five abundant families of the study area

Family	No of Species	Percentage
Asteraceae	16	14.5%
Fabaceae	13	11.8%
Poaceae	8	7%
Lamiaceae	7	6.4%
Rubiaceae	5	4.5%

As indicated in Table 3, Asteraceae was the highest abundant family represented by 16 species (14.5%), followed by Fabaceae that contributed 13 species (11.8%) while the rest are represented by less than ten species. The top five families containing the highest species numbers are represented in Figure 7.

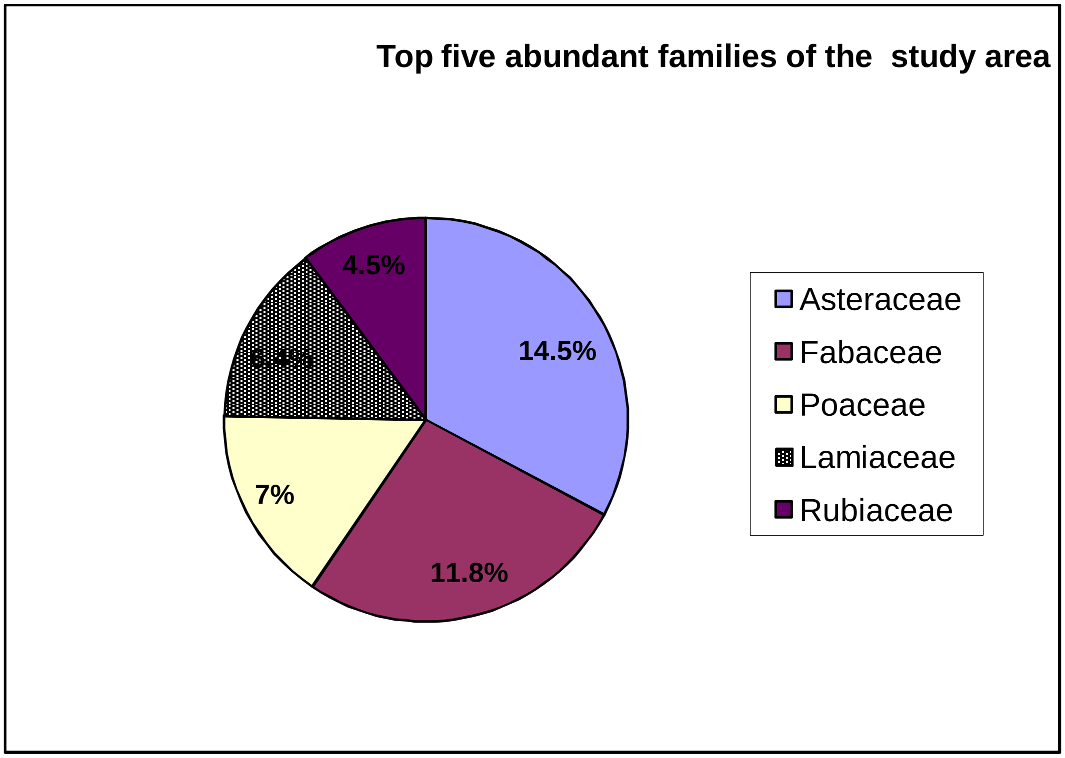

Figure 7: Percentage of the top five abundant families having high species number in the study area.

As indicated by the pie diagram, out of 110 different species (a total of 48 families) collected from the study area, 49 (44.2%) are covered by the above five mentioned families, of which Asteraceae comprises the highest number of species. The complete lists of Family-wise percentage distribution of species are shown in Appendix 7. The cluster analysis of vegetation was based on the abundance data of species that were collected within the quadrats. The result of this study revealed that the study area is one of the dry afromontane forests in central Ethiopia with respect to plant species diversity. The overall species richness of the area can give a general overview of their diversity. There are six endemic plant species in the study area as recorded in Flora of Ethiopia and Eritrea. These include: *Crassocephalum macropappum, Erythrina brucei, Inula confertiflora, Vernonia leopoldii, Kalanchoe petitiana*, and *Lippia adoinsis* (full description is shown in Appendix 9). Of these, the first four are strictly endemic to Ethiopia while the last two are endemic to Ethiopia and Eritrea. All are not under immediate threats.This is because they all belong to the least concern (LC) IUCN categories. A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened (IUCN, 2001). Florestic description of the study area implied the predominance of small sized individuals and the rare occurrence of large and woody species. This indicated the area had been under heavy exploitation and degradation and is in a stage of secondary development.

4.1.1 Growth habits distribution

The distribution of Plant Species by their habits in the study area is shown below in Figure 8.

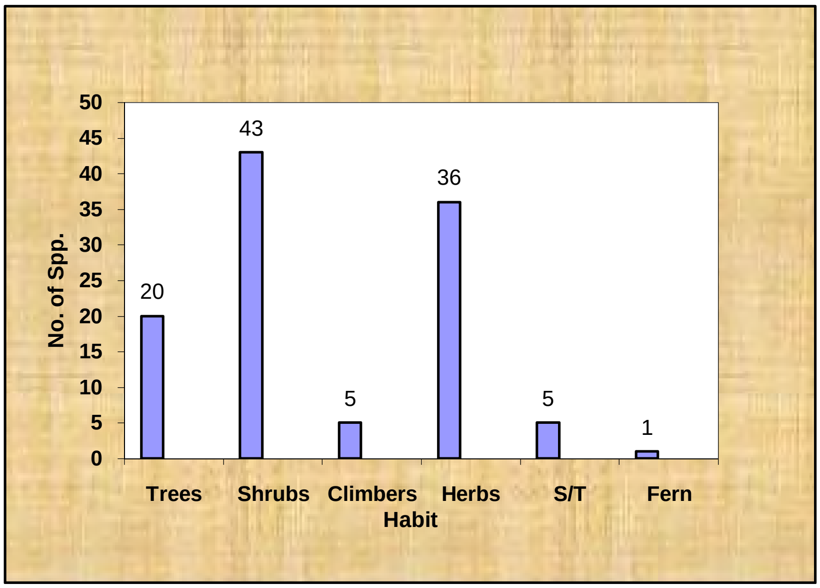

Figure 8: Distribution of plant species by their habits

In terms of growth habits distribution, shrubs were the most common and stood first with 43 species (39.1%), followed by herbs 36 species (32.7%), trees 20 species (18.2%), shrubs/trees by five (4.6%), climbers by five species (4.6%) and ferns by one (0.9%). Shrubs had the highest composition followed by herbs and then trees (Figure 8). Climbers and srubs/trees comprised equal amount of species. This indicates that the plant community of the study area is characterized by vegetation dominated by shrubs, often also including herbs, trees and other habits of plants.This might be resulted from a wide range of adaptations to fire, soil acidity, tolerance to disterbunces and hence fast growing.

4.2. Vegetation Classification (Plant Community Types)

Hierarchical classification of the plant species into different communities has been done by agglomerative hierarchical classification using similarity ratio. Based on the analysis of abundance data of species, five plant community types (clusters) were identified from the classification strategies (Figure 9). These include community types 1, 2, 3, 4, and 5. This shows that the sample quadrats that are close together correspond to sites that are similar in species composition and hence belong to the same community. The community types varied in size, ranging from 5-17 plots.

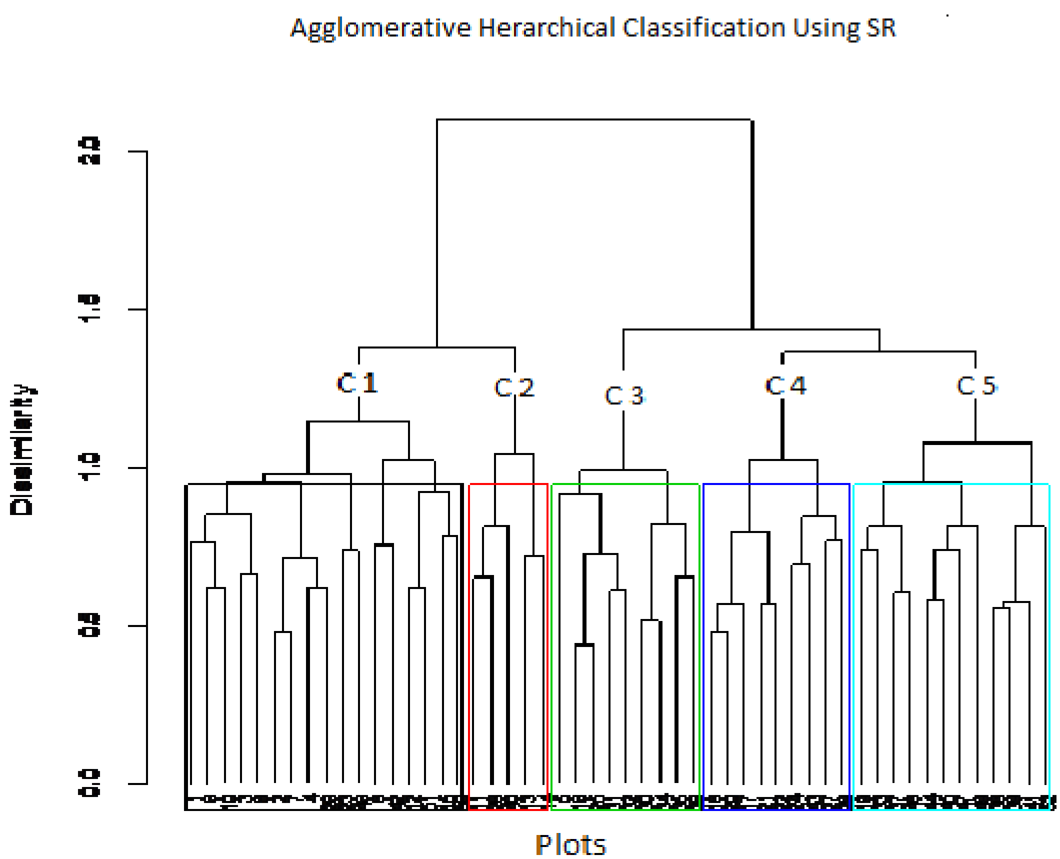

Figure 9: Dendrogram showing community types of the study area

The plot code and arrangement of plots along the dendrogram of each community type are as follows:

C1: (plots 1, 2, 3, 4, 6, 7, 8, 9, 10, 12, 15, 23, 28, 42, 48, 50, 51)

C2 : (Plots 11, 13, 14, 26, 40)

C3: (Plots 5, 18, 25, 30, 31, 32, 34, 35, 38)

C4: (Plots 16, 17, 20, 21, 22, 24, 27, 29, 43)

C5: (Plots 19, 33, 36, 37, 39, 41, 44, 45, 46, 47, 49, 52)

The five clusters were disgnated as plant community types based on the values of their synoptic cover. Diagnostic species of each community types are given in Table 5.

Table 5. Synoptic cover-abundance values of diagnostic species and other species having a value of ≥ 2.0 in at least one community type**.**

Community types	1	2	3	4	5
Community size*	17	5	9	9	12
Acacia dolichocephala	0.00	0.00	0.00	**2.00**	0.88
Albizia schimperiana	0.69	0.00	0.00	1.86	2.63
Bidens pilosa	0.00	**2.50**	0.71	0.29	0.00
Bidens prestinaria	0.23	2.00	0.71	0.29	0.25
Calpurnia aurea	0.54	0.00	1.43	2.29	3.19
Capparis tomentosa	0.00	**2.00**	0.57	0.00	0.44
Carissa spinarum	1.08	3.50	3.43	1.64	1.88
Croton macrostachyus	0.00	1.50	0.57	3.71	4.06
Cynodon dactylon	0.31	0.00	2.57	1.79	1.56
Erythrina brucei	0.00	0.00	**1.43**	0.00	0.00
Euphorbia abyssinica	0.46	0.00	0.57	2.79	0.38
Galinsoga quadriradiata	0.15	3.00	0.57	0.29	0.00
Galium aparinoides	**0.54**	0.00	0.00	0.00	0.00
Hypoestes forskaolii	0.69	2.00	0.71	0.00	0.13
Juniperus procera	0.00	0.00	**0.86**	0.00	0.00
Maesa lanceolata	3.38	3.50	0.00	0.36	0.00
Microlepia strigosa	0.15	**1.00**	0.00	0.00	0.00
Olea europaea	2.15	3.50	2.14	1.71	1.06
Pennisetum riparium	1.62	0.00	0.43	3.14	1.00
Pennisetum villosum	0.00	0.00	0.00	**0.79**	0.00
Phytolacca dodecandra	0.00	0.00	0.00	0.00	**0.75**
Premna schimperi	0.00	0.00	1.43	1.36	2.88
Pterolobium stellatum	0.00	1.50	1.71	0.93	2.94
Rhus vulgaris	2.15	3.50	0.57	0.43	0.56
Rosa abyssinica	**3.92**	0.00	0.00	0.00	0.00
Rubus steudneri	0.77	3.00	0.57	0.21	0.50
Rytigynia neglecta	0.00	0.00	0.00	0.00	**0.81**
Vernonia amygdalina	0.62	0.00	**2.14**	0.00	0.00
Vernonia auriculifera	0.77	3.50	2.00	1.36	1.19

* Number of quadrats grouped in each community type; highlighted numbers (values in bold) in the table represent the diagnostic species which preferably occur in a single vegetation unit (character species) or in a few vegetation units (differential species) i.e., species with high degree of fidelity (the degree to which species are confined to particular group of quadrates). Species are listed according to their alphabetical order. Finally, the following plant communities have been named by two diagnostic species based on highest mean cover/abundance value that confined to particular cluster. The plant community types and their characteristics are listed and described below.

4.2.1. *Rosa abyssinica- Galium aparinoides* community type

This community type is located relatively at higher elevation between the altitudinal range of 2023 and 2554 m a.s.l. The community comprises 17 plots and 68 species. Compared to the other communities, this community has the largest number of plots (17 plots) and contains 68 species. It also contains the largest number of indicator species and is the most species rich community. This richness could have resulted from its wide range of altitude and number of plots. Along with the indicator species used to name the community, *Rhus vulgaris*, *Olea europaea*, *Pennisetum riparium*, *Olinia rochetiana*, *Rhamnus staddo*, *Myrsine africana*, *Hyparrhenia dregeana* and *Carissa spinarum* are among the dominant species in the community. *Rosa abyssinica* is characteristic species that occurs only in this community type.

Most stands sampled in this type are located in Tulu Facha shrubland, around Asgori (East of Ambo) which is less grazed by cattle. Most quadrats in this community type were relatively far from human encroachment so that its human impact is found to be relatively low and contributed relatively high species diversity and species richness. Moreover, high slope natures of the site that are not easily accessible by local people to disturb it may also influence it. There was high regeneration of many plant species in most quadrats which may result from the optimum environmental conditions associated with elevation within the community.

4.2.2. *Bidens pilosa - Microlepia strigosa - Capparis tomentosa* communitytype

This community type compared to the rest three communities has the least number of plots (5 plots) and 17 species are associated with this community type. It occurs within the altitudinal range of 2008 and 2536 m a. s. l. Other associated species to the dominant and character species mentioned in the type include *Rhus vulgaris*, *Vernonia auriculifera*, *Rubus steudneri*, *Bidens pilosa*, *Bidens prestinaria*, *Galinsoga quadriradiata*, *Capparis tomentosa*, *Hypoestes forskaolii*, *Rhamnus staddo*, *Microlepia strigosa*, *Osyris quadripartita* and *Andropogon abyssinicus*. *Microlepia strigosa* (fern) is a species that occurs only in this community type. Like the first community type, they occur on a slightly hillsides and in seasonally flooded landscape. Most dominant species of the type were herbs. i.e., *Bidens pilosa, Bidens prestinaria, Hypoestes forskaolii* and *Andropogon abyssinicus were the* herbaceous layer species.

4.2.3. *Vernonia amygdalina - Erythrina brucei –Juniperus procera* community type

In addition to indicator species the dominant tree species of the community include *Acacia mearnsi, Erythrina brucei, Olea europaea and Cordia africana. Acacia mearnsi. Erythrina brucei, and Vernonia amygdalina* are characteristic species that occur only in this community type. The dominant shrub of this community was *Vernonia amygdalina, Vernonia auriculifera, Calpurnia aurea, Pterolobium stellatum and Premna schimperi. Hyparrhenia dregeana, Sporobolus africanus, and Datura stramonium* were the herbaceous layer species. The climber species, *Clematis simensis*, was also associated with this community. The community type is distributed between 2062 and 2537 m a.s.l. and comprises nine plots and 48 species.

This community type is rich in shrub layer species and woody climbers. The stands sampled in this community are located in Tulu Miessa (South of Ambo) with medium human interference in the form of firewood collection and selective cutting and this could be because of having species of plants suitable for furniture making and firewood.

4.2.4. *Acacia dolichocephala - Pennisetum villosum* community type

Associated species in the type include *Calpurnia aurea, Acacia dolichocephala*, *Albizia schimperiana*, *Cynodon dactylon*, *Andropogon abyssinicus*, *Olea europaea* and *Carissa spinarum*. *Acacia dolichocephala* is the characteristic species of the type. Some of the trees in

this community are *Croton macrostachyus*, *Olea europaea*, and *Acacia dolichocephala*.
This community is found at altitude from 2084 and 2190 m a.s.l. and comprises nine plots and 61 species. The most dominant herbaceous layer species were *Pennisetum riparium.* Other herbaceous layer species were *Cynodon dactylon* and *Andropogon abyssinicus.* Community type 4 has experienced human interference in the form of selective cutting. Cattle interferences and overgrazing were also observed in most of its stands. This might be due to being near to the farmer's settlement area.

4.2.5. *Rytigynia neglecta - Phytolacca dodecandra* community type

This community type is distributed between the altitudinal ranges of 2002 and 2182 m a.s.l. The community comprises 12 plots and 78 species. It is dominated by *Albizia schimperiana*, *Ficus vasta*, *Cordia Africana* and *Acacia albida* among the tree species and *Pterolobium stellatum*, *Premna schimperi, Carissa spinarum, Euclea divinorum* and *Grewia ferruginea* are among the shrub species. The herb layer is dominated by *Sporobolus africanus* and *Echinops longisetus. Ficus vasta* and *Grewia ferruginea* were the characteristic species of this community type.
Community type 5 is highly influenced by people collecting firewood, charcoal making and grazing animals. This is due to its partially being nearby to Ambo town and parts of the area specially, towards Wadessa were being hidden from the local forest guards and having species of plants suitable for charcoal making and firewood. This community type with good timber species: *Juniperus procera, Olea europaea* subsp. *cuspidata* and *Ficus vasta* has experienced human interference in the form of selective cutting. The stands of this community are from an area, which is relatively at lower altitudes.

Classification of the identified plant communities matched more or less with the altitudinal variation recorded, implying that altitude is the most important environmental element that determined occurrence and distribution of the plant communities. It has been long recognized that altitude is an important environmental factor that affects radiation, atmospheric pressure, moisture and temperature, all of which have strong influence on the recruitment, growth and development of plants and the distribution of vegetation types (Hedberg, 1964; Kumelachew & Tamrat, 2002). Species diversity in the study area varies across altitude even if it is not so much. The communities at the bottom and top of the altitudinal gradient were found to be rich in species composition while the community restricted to the middle was relatively poor in species composition.

4.3. Species Richness, Evenness and Diversity of the Plant Community Types

Shannon and Wiener (1949) diversity index for the five communities from the vegetation data of the study area is given in Table 6. The plant community types showed variation in their species richness, evenness and diversity. The highest species richness (74) and diversity (3.88) were found in community type 1. The high species richness could probably be attributed to the optimum environment that supports the species and the minimum level of disturbances (i. e. the greater diversity in any community can be attributed to the amount of disturbance in the quadrat). In this community, most representative plots are found far from anthropogenic disturbances which are less susceptible to such disturbances. Moreover, high slope natures of the site that are not easily accessible by local people to disturb it may have also influenced it. Community type 5 exhibited the second highest species richness and evenness. Community type 3 had the highest evenness but the least species richness which could be attributed to anthropogenic activities and/or browsing by domestic animals. The species diversity, evenness and richness value difference may be due to the altitudinal variation; number of plots included, species occurrence and some anthropogenic effects. Generally, the high value of species richness has a great importance in assessing taxonomic, structural and ecological value of the forest.

Table 6: Species richness, evenness and diversity in the five plant community types (Shannon Wiener diversity index).

Communities	**Altitude(m)**	**Species richness**	**Diversity index (H`)**	**Shannon Evenness**
1	2023m-2554 m	74	3.881999	0.901938
2	2008m-2536 m	44	3.394285	0.896965
3	2062m-2537 m	38	3.397714	0.934057
4	2084m-2190 m	57	3.658339	0.904846
5	2002m -2182 m	70	3.859177	0.908363

Where, H'= Shannon Weiner diversity index (diversity assuming all the constituent species are evenly distributed); Species richness = total number of species recorded in all of the quadrats grouped in each plant community type.

Species evenness shows the relative proportional abundance of a species in quadrats. Low evenness value implies the dominance of the environment by few species. Based on this, community 3 followed by communities 5 and 4 has the highest evenness value.

As indicated in Table 5, the five communities have almost the same species distribution (equitability or evenness) but comparatively community 3 has the highest species evenness and community 2 has the least species evenness value while the rest communities (communities 1, 4 and 5) have intermediate evenness. The lowest species evenness was found to be in community type 2. This can be due to the small number of plots included. The reason for closeness of diversity and evenness of some communities could be attributed to relatively comparable altitudinal ranges. High species richness and diversity could be attributed to optimal conditions of environmental factors that are associated with intermediate altitudes.

Results of the study indicated that altitude determined distribution of the plant communities identified in the study. For instance, greater vegetation cover and higher number of species were found at higher altitudes and lower altitudes. Plant community type 1, which was found at an altitude of 2023-2554 m, exhibited the highest species richness. Moreover, plant community type 5, which was found at an altitude of 2002 -2182 m, also showed the second species richness and diversity.

In general, the probable reasons for the variability of each magnitude (value) for the different community types arise from altitude, degree of disturbance involved in the area, cover abundance value and other environmental factors (slope, soil and aspect) which were not included in this study. As indicated earlier, clearing bushes for cultivating crops, fuel wood, construction material, farm implements, edible fruits, honey, medicinal plants and fence at the study sites seem an inevitable activity. This activity may influence species richness, diversity, evenness and structure of the plant communities identified in the study area.

4.4. Population Structure

4.4.1. Frequency of plant species in the study area

Frequency is the number of quadrats in which a given species occurred in the study area. In the study area, the most frequent top ten species with a frequency value greater than 30 percent are shown in Table 6. The frequency and percentage frequency values of each species are described (Appendix 4). The frequency was determined from the number of quadrats where the species were recorded from a total of 52 quadrats. It was found that *Carrisa spinarum* is the most frequent species (55.8%) occurring in 29 quadrats sampled and followed by *Croton macrostachyus (*53.8%) recorded in 28 quadrats and the third is *Olea europaea(52%)*recorded in 27 quadrats. In the study area species with more than 50% distribution were *Carrisa spinarum* (55.8%), *Croton macrostachyus (*53.8%), *Olea europaea (52%)* and *Calpurnea aurea* (50%) all of which are woody species. Twenty six species are the least, contributing 1.9 % each to the frequency distribution (Appendix 4).

Table 7: Percentage frequency (percentage >30) distribution of most frequently occurring species in the study sites.

Species	No of quadrats	Total quadrats	Frequency (%)	Relative frequency (%)
Carrisa spinarum	29	52	55.8	3.8
Croton macrostachyus	28	52	53.8	3.7
Olea europaea	27	52	51.9	3.6
Calpurnia aurea	26	52	50.0	3.4
Pennisetum riparium	23	52	44.2	3.0
Premna schimperi	20	52	38.5	2.6
Vernonia auriculifera	20	52	38.5	2.6
Rhus vulgaris	19	52	36.5	2.5
Pterolobium stellatum	18	52	34.6	2.4
Andropogon abyssinicus	17	52	32.7	2.3

Frequency is the number of times a particular species is recorded in the sample area. The frequency distribution of tree species was calculated as follow:

$$\% \text{ frequency of species} = \frac{\text{No. of quadrats in which species A occurs}}{\text{total No.of quadrats examined}} \text{X100}$$

$$\text{Relative frequency(RF)} = \frac{\text{No. of quadrats in which species A occurs}}{\text{total occurence for all species of the sample}} \text{X100}$$

As it is clearly depicted in Table 7, compared to frequent plant species existing in the study area, it was recorded that *Carrisa spinarum* is the most frequent species than the other species. It is also to be noted that this species is favoured by anthropogenic disturbance of natural vegetation. Furthermore, unlike the others, it is not harvested for firewood (because of its spiny nature), building, not browsed and grazed compared to others in the area. In fact, the plant is popular among the society for its edible fruit and fence service. *Croton macrostachyus* grows fast and is unpalatable to both domestic and wild animals; the tree grows quite successfully (Legesse Negash, 2010). Analysis of the frequency distribution indicated that *Carrisa spinarum, Croton maccrostachyus, Olea europaea* subsp. *cuspidata, Calpurnia aurea, Pennisetum riparium, Premna schimperi, Vernonia auriculifera, Rhus vulgaris, Pterolobium stellatum and Andropogon abyssinicus* were found to be with the highest relative frequency indicating their good distribution throughout the study area.

4.4.2 Stem density

A total of 540 tree species (259.7 individuals /ha) were counted with the DBH > 2 cm within sampled quadrats. The density of some of these tree species is given in Table 7. Among the tree species *Croton macrostachyus* has the largest number. There were 91 *Croton macrostachyus* individuals within 2.08 ha. followed by *Olea europaea* subsp. *cuspidata* and *Calpurnea aurea* which have density 79 and 68 per hectare respectively. *Olea europaea* ssp. *Cuspidata* is the tree species recorded in all community types. *Croton macrostachyus, Olea europaea* subsp. *cuspidata* and *Calpurnia aurea* were the most common (frequent) tree species in many sample plots whereas *Ficus thonningii*, *Grevillea robusta* and *Juniperus procera* (1.9% each) were the rare species in the study area.

Table: 8 List of tree species recorded with their densities and frequencies.

No	Name of species	Total count	Density	RD (%)	No. of quad. /spp.	Total qua.	Friquency (%)	RF (%)
1	*Albizia schimperiana*	42	20.2	7.8	16	52	30.8	8.4
2	*Calpurnia aurea*	68	32.7	12.6	26	52	50.0	13.6
3	*Cordia africana*	28	13.5	5.2	7	52	13.5	3.7
4	*Croton macrostachyus*	91	43.8	16.8	28	52	53.8	14.7
5	*Erythrina brucei*	3	1.4	0.6	2	52	3.8	1.0
6	*Euphorbia abyssinica*	12	5.8	2.2	10	52	19.1	5.2
7	*Ficus vasta*	7	3.4	1.3	5	52	9.6	2.6
8	*Grevillea robusta*	1	0.5	0.2	1	52	1.9	0.5
9	*Juniperus procera*	1	0.5	0.2	1	52	1.9	0.5
10	*Maesa lanceolata*	55	26.4	10.2	15	52	28.8	7.9
11	*Olea europaea*	79	38.0	14.5	27	52	51.9	14.3
12	*Olinia rochetiana*	16	7.7	3.0	7	52	13.5	3.7
13	*Acacia albida*	40	19.2	7.4	12	52	23.1	6.3
14	*Acacia dolichocephala*	28	13.5	5.2	10	52	19.1	5.2
15	*Acacia mearnsii*	24	11.5	4.4	6	52	11.5	3.1
16	*Acacia sieberiana*	9	4.3	1.7	7	52	13.5	3.7
17	*Celtis africana*	14	6.7	2.6	2	52	3.8	1.0
18	*Ficus thonningii*	1	0.5	0.2	1	52	1.9	0.5
19	*Eucalyptus camaldulensis*	18	8.7	3.3	6	52	11.5	3.1
20	*Cupressus lusitanica*	3	1.4	0.6	2	52	3.8	1.0
	Total	540	259.7	100	183		366.8	100

4.4.3 DBH-class distribution

Among the woody species recorded in the study area, the distribution of tree species in different diameter class is shown in Appendix 5. Five DBH classes were conventionally established (Figure 12). Most of the species in the area are confined in the low diameter class distribution. The highest numbers of individuals were found in the diameter class of 2–10 cm declining with increasing diameter. However, there was not big difference between the first two diameter classes. About 69.3% (almost 3/4th) of the individuals were found in the first two classes (2-10 and 10-20 cm) indicating the potentiality of the surveyed shrubland for future production and improvement capability of all the species if appropriate management practice is going to be applied. The remaining four classes together account for about 30.7%. Therefore, the result shows that the majority of the species had the highest number of individuals in the lower DBH and low in the high DBH classes. The large proportion of small-sized tree individuals suggest that the vegetation of the area has good reproduction potential.

When viewed from the whole set of population structure, the general pattern of DBH class distribution of the woody species showed an inverted J-shape with many small stems compared to few large ones (Figure 12). Such reversed J-shaped distribution pattern depicts that the area is on the status of favorable regeneration and recruitment potential. Population structure of species can show whether the population has a stable distribution that allows continuous regeneration to take place or not. If regeneration were taking place then the species would have a stable population distribution with reversed J in shape, which is an indicator of healthy regeneration. Such population structure (reversed "J" shape) is common in natural forests where external disturbances are limited. Human caused disturbance such as intensive removal of trees for timber, construction and fuel can place significant pressure on regeneration status of the selectively removed species. Population structures of trees in the forest and factors affecting their potential regeneration have significant implications to the management, sustainable utilization and conservation of the forest.

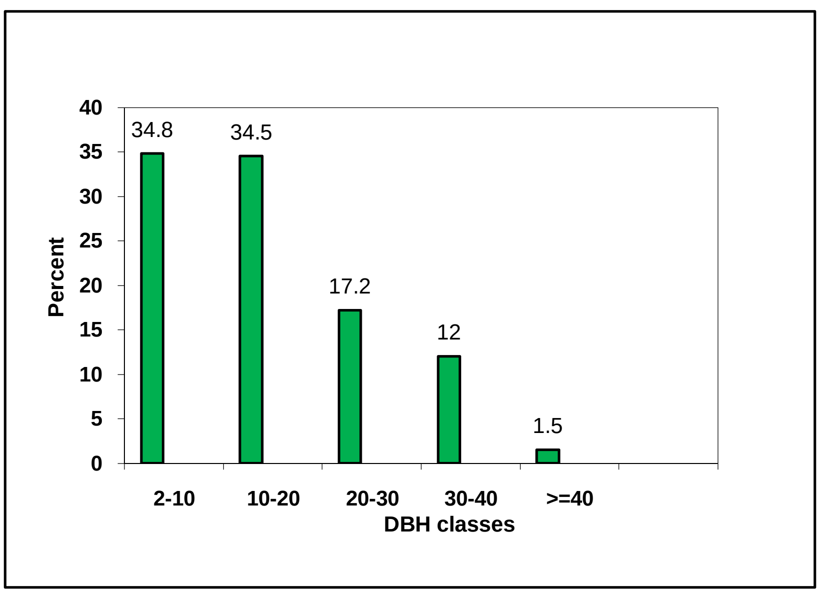

Figure 10: A graph showing percentage distribution of trees in DBH - classes (cm).

For the analysis of trees with DBH > 40 cm, the highest contributors (1.5%) were *Ficus vasta* and *Cordia africana* which might have resulted from the selection of the tree by local farmers as a shade for their cattle and its edible fruit for cattle herders.

However, it is to be noted that when the entire DBH class distribution of the area is evaluated on a species basis, different population dynamics for different species were revealed. For example, *Albizia schimperiana* (Figure 11), *Croton macrostachyus and Calpurnia aurea* have a reversed J-shaped distribution, while *Olea europaea* has irregular distribution (Figure 12). These could be due to selective cutting of species by the local people for timber and other domestic uses or they had tolerance to disturbance and hence fast growing. On the other hand, from the result it is possible to suggest that the low stocking level of mature trees confirmed that the study area is affected by collection of fuel wood, for household consumption, for sale and construction poles.The DBH-class distribution of two-selected tree species *Albizia schimperiana and Olea europaea* ssp. *cuspidata* are shown below. The DBH measurements show the largest proportion (10.6 individuals /ha) of *Albizia schimperiana* is found to be between 2-10 cm diameter class.

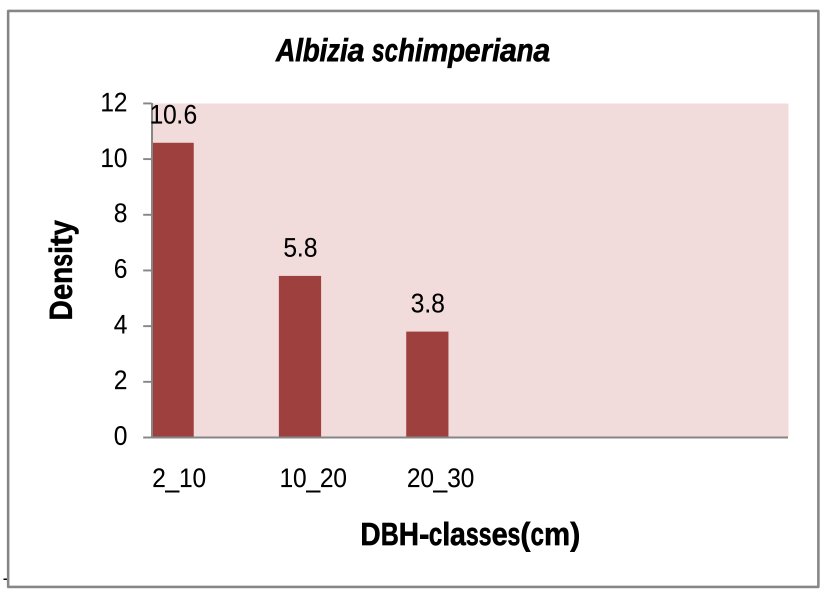

Figure 11: DBH class and density of *Albizia schimperiana* showing reversed J shaped distribution.

The DBH distribution of *Olea europaea* ssp. *cuspidata* (Figure 14) indicate that a considerable proportion (12.4 individuals/ha) is between 20-30 cm DBH class. The largest proportion (14.1 individuals/ha) of *Olea europaea* ssp. *cuspidata* is recorded in the lower DBH-class (2-10 cm) and the least proportion is found in DBH class 30-40 cm. This could be due to selective cutting of this tree which has lowered the proportion of some height-classes.

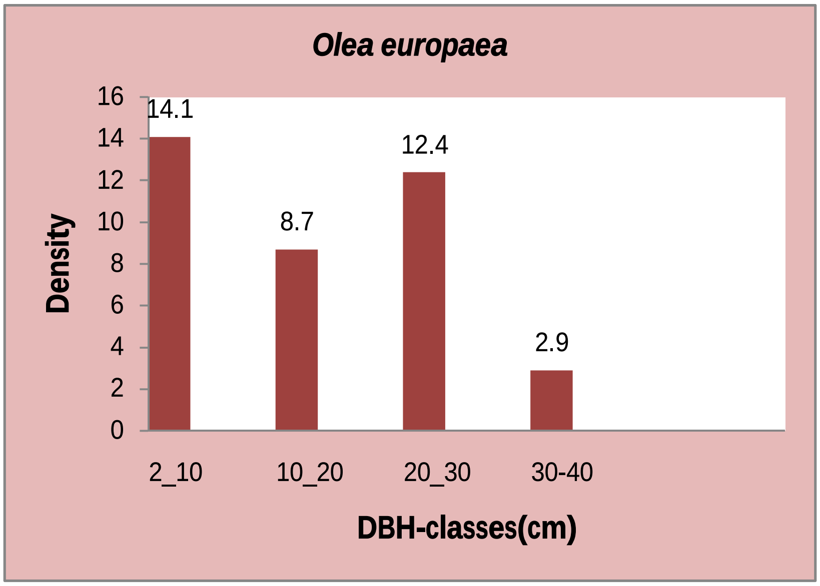

Figure 12: DBH class and density of *Olea europaea* showing irregular distribution.

4.4.4 Height-class distribution

The tree species in the study area could be conveniently classified into five height classes: 2 -6 m, 6.1-11 m, 11.1-16 m, 16.1-21 m and > 21 m. The percentage height class distribution of the species is presented in Table 9. The height class distribution follows similar trend with that of the DBH-class distribution. Most of the tree species in the study area belonged to the smallest height class group. A considerable proportion of the individuals (69.7%) belong to the lowest height classes i.e. (<11 m). Only few individuals (2.3%) attain heights of more than 21 m.

Table 9: Percentage distribution of trees in height classes (m).

	Height class in m	%
1	2-6	35.2
2	6.1-11	34.5
3	11.1-16	20.2
4	16.1-21	7.8
5	>=21	2.3

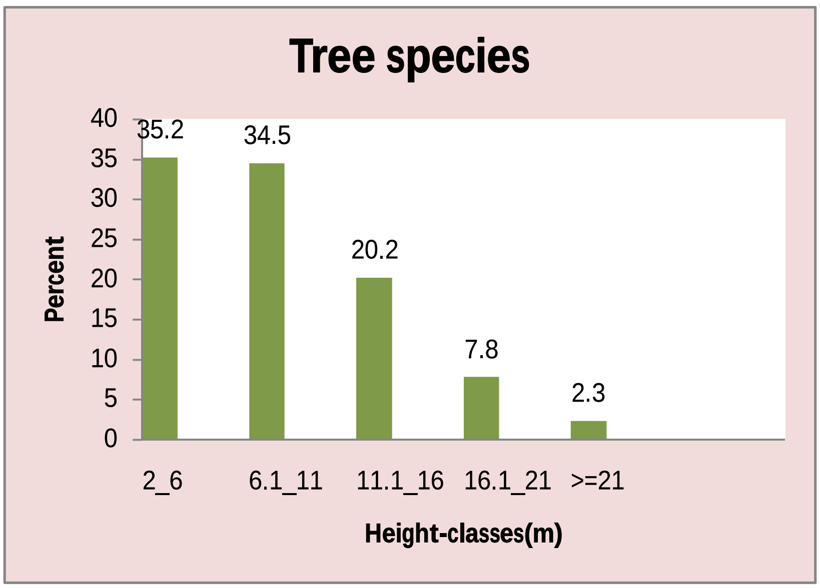

Figure 13: Percentage distributions of trees in height classes (m).

From Figure 13, it is evident that the density of each height class decreases with the increase in height showing an inverted J-shape distribution pattern indicating stable population structures. There are enough individuals in the lower classes to replace the old individual plants (Table 10). The decreasing density of height class towards the highest height classes reveals the dominance of small sized individuals in the area which was the attribute of high rate of regeneration but poor recruitment. This may be due to selective cutting of large sized individuals. Feyera Senbeta and Demel Teketay (2002) also stated that the dominance of shrubs and small trees in the floristic composition of the forest suggest that bigger tree species are selectively removed or exploited.The emergent tree species which had the highest height in the study area were *Eucalyptus camaldulensis, Ficus vasta and Cordia africana* represented by about 2.3% (> 21m).

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 determine the vertical structure of the stand (Pascal *et al*., 1996). Variation in tree height is an important ecological phenomenon which affects the microclimate and distribution of epiphytes and climbers (Tamrat Bekele, 1993).

Among species, there are variations in height distribution patterns. For example, bell-shape (*Acacia dolichocephala and Ficus vasta)*, an inverted J-shape (*Calpurnia aurea* and *Croton macrostachyus)* and an irregular increase or decrease (*Acacia albida*) (Figures 13-15).

The distribution of three tree species: *Acacia dolichocephala*, *Croton macrostachyus* and *Acacia albida* was observed and briefly discussed below to see the state of the vegetation.The height-class distribution of *Acacia dolichocephala* is shown below (Figure 14).

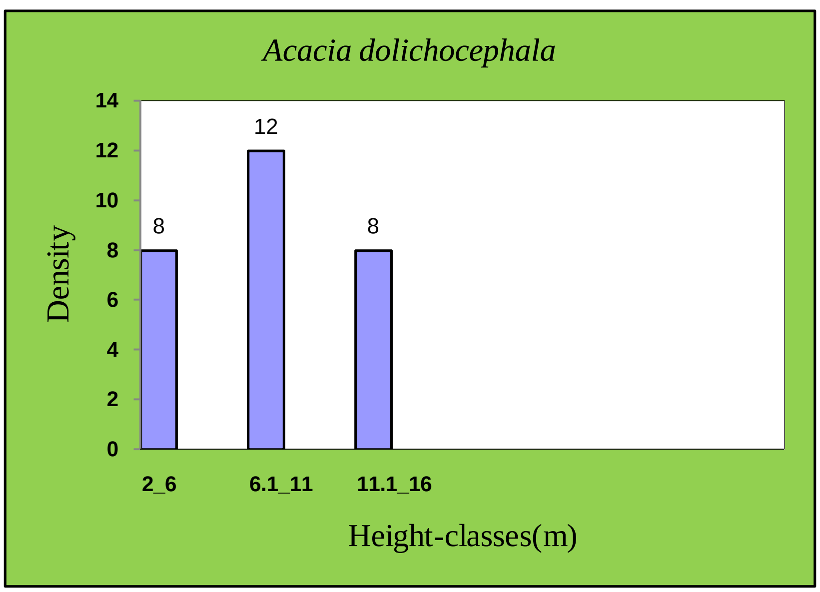

Figure 14: Population structure of *Acacia dolichocephala* (bell-shaped distribution).

The largest proportion of *Acacia dolichocephala* is found in the height class 6.1-11 m. This might be due to selective cutting by the local people for different purposes.

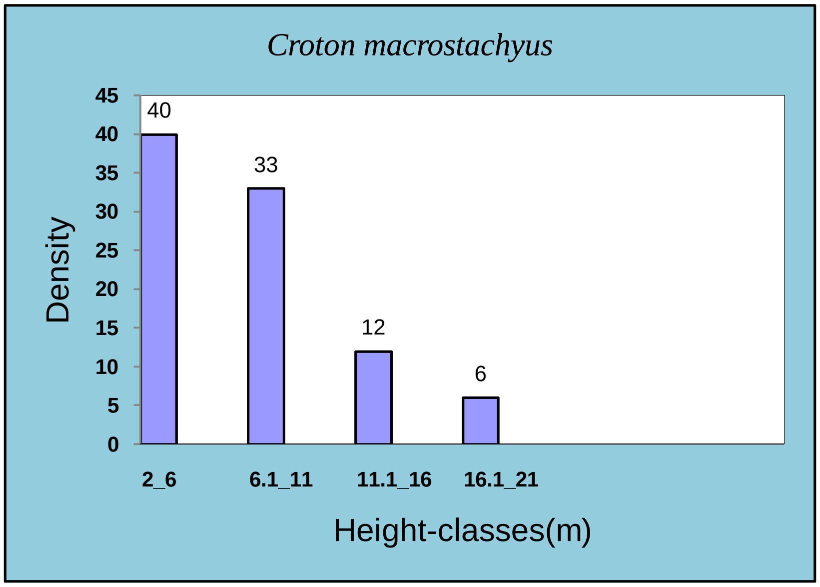

Figure 15: Population structure of *Croton macrostachyus* (Inverted J- shaped distribution).

The highest proportion of the species *Croton macrostachyus* was recorded in the lowest (2-6 m) height-class group followed by the next lower height-class 6.1-11 m. Similar trend with most other trees has been observed in the height-class distribution.This is because, *Croton macrostachyus* grows fast and is unpalatable to both domestic and wild animals; the tree grows quite successfully (Legesse Negash, 2010).

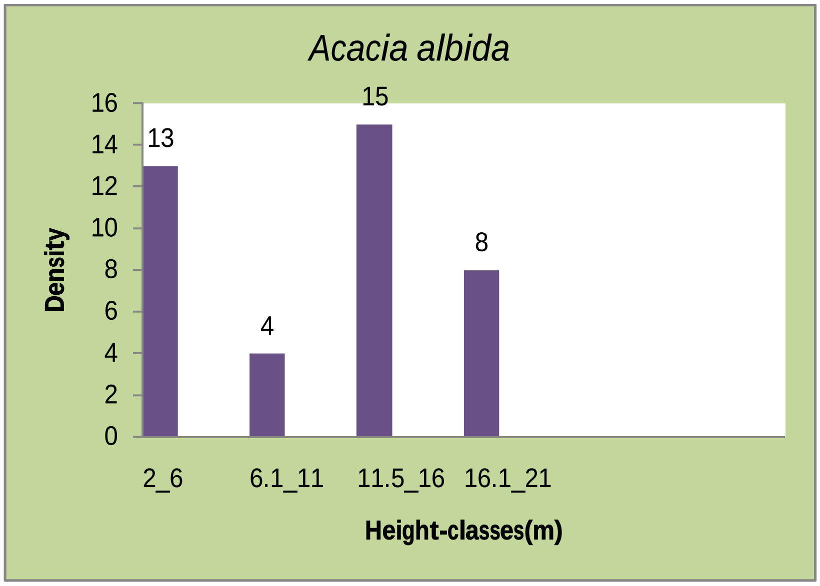

Figure 16: Population structure of *Acacia albida* (Irregular- distribution).

Substantial proportion of *Acacia albida* is found in the middle height-class (11.1-16 m) distribution followed by the lowest height class (2-6 m). Selective cutting of these trees has lowered the proportion of some height-classes and favoured the other height classes (Figure 16). Only few proportions are above 16 m. Variation in population structure was revealed from the DBH analysis for tree species. In general, the density of tree species decreases with increasing DBH and height indicating the predominance of small-sized individuals in the study area.

Density distribution at different height classes in the study area showed that 35.2 % of the individuals have a height less than 6 meters. This implies that the shrubland is in a good state of recruitment.Thus the study confirms that the number of individuals decreased as the height of the individuals increased indicating long time disturbance. Density distribution at different DBH classes also showed similar trend as that of height class distribution. It indicates dominance of small sized individuals.

4.5. Conclusion and Recommendations

4.5.1 Conclusion

From the study of the shrubland vegetation around Ambo, 110 species of plants belonging to 98 genera and 48 families were identified, of which 39.1% were shrubs , 32.7% were herbs, 18.2% were trees, 4.6% were trees/shrubs, 4.6% were climbers and 0.9% fern. These plants are largely angiosperms except one fern species and two gymnosperm species. Asteraceae had the highest number of species followed by Fabaceae. These dominant families might have well developed strategies and adaptations which helped them successfully to survive in the area. Out of 110 species four were endemic to Ethiopia.

Results of the present study revealed that the vegetation in the study area is grouped into five different community types each of which had varying degrees of species richness, diversity and evenness. The variation prevailed among communities could be due to different factors (soil moisture, altitude, anthropogenic factors, etc,). These communities are: *(i) Rosa abyssinica-Galium aparinoides* community at altitude between 2023 and 2554 m, *(ii) Bidens pilosa - Microlepia strigosa - Capparis tomentosa* community at altitude between 2008 and 2536 m, *(iii) Vernonia amygdalina - Erythrina brucei-Juniperus proce* community at altitudes between 2062 and 2537 m, *(iv) Acacia dolichocephala - Pennisetum villosum* community at altitudes between 2084 and 2190 m *and (v) Rytigynia neglecta - Phytolacca dodecandra* community at altitude between 2002-2182 m. There is no clear boundary of species distribution in the area. This can be attached to the high human interference because of the proximity of the vegetation to human habitations. However, species diversity in the study area varies slightly across altitude. Plant community type 1, which was found at altitudes between 2023 and 2554 m, exhibited the highest species richness and diversity.

In most parts of the surveyed area evidence of exploitation (e.g. cutting and fuel wood collection) has been observed. In addition to this, the shrubland vegetation of the study area is disturbed through grazing and browsing by livestock and other human uses (personal observation).

Analysis of species population structure pointed out the variability of population dynamics in the vegetation of the area: species able to regenerate in the study area (e.g. most trees) and large and old trees with difficulties to reproduce in the environments (e.g. *Ficus vasta*). Further more, the DBH and Height-Class distribution analyses have shown that there are similar trends in both diameter and height. The proportion of trees having higher diameter as well as height decreased as the distribution class increased which confirms that majority of them showed a reversed J-shape. A total of 20 tree species of DBH > 2 cm having total individuals of 540 (259.7 individuals/ha) were recorded. Out of these, 69.7% of them are below 12 m long. This shows the dominance of small sized speies in the shrubland vegetation of the area. The most frequent tree species are *Croton macrostachyus, Olea europaea* and *Calpurnia aurea.* The total density of tree species having DBH >2 cm is 540 (259.7 stem per hectare) where *Croton macrostachyus, Olea europaea* and *Calpurnia aurea* contributed for 14.7%, 14.3% and 13.6% respectively.

In general, the survey showed that the study area is dominated by small sized tree and shrub species in its secondary stage of development, indicating that the forest was heavily exploited and affected in the previous periods, but good regeneration is in process at the present time. Therefore, to improve the natural diversity and structure of the area, to minimize the influence of the surrounding communities and utilize the forest resources sustainably for present and future generation, the basic needs and traditional rights of the communities over the uses of vegetation resources should be recognized. The much-needed positive attitudes towards vegetation protection and development can only be obtained from the rural communities through the development of a genuine benefit sharing mechanism. Thus community participation is quite important. Recognizing these issues as possible future scenario underlies the need for management intervention to increase quality of regeneration being recruited and to accelerate the growth of the young plants already present.

4.5.2 Recommendations

Plants regulate microclimate, protect water resources, provide forest products and are homes to plant and animal species. However, from the forgoing discussion it can be seen that the vegetation requires better management so that its resources could be effectively utilized on a sustainable bases. Therefore, the following recommendations are made to meet these requirements:

- Among the threats to the vegetation of the area, expansion of farm land, clearing for charcoal, construction and other domestic uses were the major ones. To minimize the risk, continuous mobilization of the local communities and building a sense of ownership and conservation interest through discussion and consultation with various stakeholders is crucial.
- Analysis of species structure shows that some important tree species like *Ficus vasta* and *Cordia africana* are in poor regeneration and recruitment conditions due to selective cutting owing to high demand for building materials. This calls for the need to take proper conservation measures by the relevant authorities.
- Proper animal husbandry (a common practice in the area as pointed by Dereje Bacha, *et al.,*2009 and from personal observation) should be put in place so that the number of heard of cattle is managed and the regeneration of the species in the forest could be facilitated.
- The study area has been found to possess scattered trees dominated by grass and shrubs. This floristic composition is supposed to be susceptible to over browsing and expansion of farmland. Thus, the local people should be aware about protection and sustainable way of utilization of the vegetation supported by rules and regulations.
- Due to time and financial constraints the study that has been made at present is just small portion. Therefore, further study is important to fill the gap of this work and to investigate what other factors such as soil chemical and physical properties would influence the distribution of the vegetation in the study area.

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6. APPENDICES

Appendix 1: List of plants recorded in the stands sampled around Ambo.
C=Climbers, S= Shrubs, T= Trees, H= Herbs, F= Ferns - = No local name.

No	Scientific name	Family	Habit	Local name (Oro.)	Coll. No.
1	*Acacia albida Del.*	Fabaceae	T	Garbii	086
2	*Acacia dolichocephala* Harms.	Fabaceae	T	Laaftoo keelloo	098
3	*Acacia mearnsii* De Wild.	Fabaceae	T	Kaachaa	017
4	*Acacia sieberiana* DC.	Fabaceae	T	Laaftoo daraaraa adii	091
5	*Achyranthes aspera* L.	Amaranthaceae	H	Maxxanne(dargu)	118
6	*Acokanthera Schimperi(*A.Dc.) Schweinf.	Apocynaceae	T	Qaraaruu	085
7	*Aeschynomene abyssinica* (A.Rich.)Vatke	Fabaceae	S	-	014
8	*Albizia schimperiana* Oliv.	Fabaceae	T	Imalaa/sesa	059
9	*Andropogon abyssinicus* Fresen.	Poaceae	H	Baallammii	029
10	*Argemone mexicana* L.	Papaveraceae	H	medafe (Amh)	051
11	*Asparagus africanus* Lam.	Asparagaceae	S	Sariitii	031
12	*Bersama abyssinica* Fresen.	Melianthaceae	S	Lolchiisaa	088
13	Berula erecta (Huds.) Coville	Apiaceae	H	Ensilale	026
14	*Bidens pilosa* L.	Asteraceae	H	Maxxannee	066
15	*Bidens prestinaria* (Sch. Bip.) Cufod.	Asteraceae	H	Keelloo boyyee	039
16	*Brucea antidysenterica* J.F. Mill.	Simaroubaceae	S	Qomoonyoo	095

Appendix1 continued

17	*Budleja polystachya* Fresen.	*Buddlejaceae*	S/T	*Anfaara*	080x
18	*Calpurnia aurea (*Ait.) Benth.	Fabaceae	T	Ceekaa	081
19	*Capparis tomentosa* Lam.	Capparidaceae	S	Harangama daalacha/Gumero	072
20	*Carissa spinarum* L.	Apocynaceae	S	Agamsa	034
21	*Celtis africana* Burm.f.	Ulmaceae	T	Caayii	087
22	Cirsium vulgare (Savi) Ten.	Asteraceae	H	Kosheshla, huuruu xaddee	049
23	*Clausena anisata* (Willd.) Benth.	Rutaceae	S	Ulumaayii	064
24	*Clematis simensis* Fresen.	Rununculaceae	C	Hidda fiitii /yeazo hareg	033
25	*Clutia abyssinica* Jub. & Spach	Euphorbiaceae	S	Ulee foonii/fiyele fej	079
26	Colutea abyssinica Kunth. & Bouche	Fabaceae	S	Kilkillee/doadoate	009
27	*Commelina benghalensis* L.	Commelinaceae	H	Laancee/yewuha ankur	078
28	*Cordia africana* Lam.	Boraginaceae	T	Waddeessa	097
29	*Crassocephalum macropappum(Sch.Bip.ex A. Rich) S. Moore*	Asteraceae	H	Qadaaddii(Lit-marefiya)	013
30	*Croton macrostachyus Hochst. ex* Del.	Euphorbiaceae	T	Bakkaaniisa	058
31	*Cupressus lusitanica* Mill.	Cupressaceae	T	Gaattiraa faranjii	037
32	*Cyathula uncinulata (*Schrad.) Schinz	Amaranthaceae	H	Maxxannee mataa goofaree	103 x

Appendix 1 continued

33	*Cynodon dactylon* (L.) Pers.	Poaceae	H	Coqorsa	056
34	*Cynoglossum coeruleum* Steud.ex DC.	Boragnaceae	H	maxxannee chati	083
35	*Cyphostemma cyphopetalum (*Fresen.*)*	Vitaceae	C	Hidda diimaa	101
36	*Datura stramonium* L.	Solanaceae	H	Asangira	111x
37	*Dichrocephala integrifolia(*~L.F) O. Kuntze	Asteraceae	H	-	028
38	*Dodonaea angustifolia* L.f.	Sapindaceae	S	Ittacha	076
39	*Dovyalis caffra (*Hook.f.& Harv.)	Flacourtaceae	S	Koshommii	035x
40	Echinops kebericho Mesfin	Asteraceae	H	Qabaricho	020x
41	*Echinops longisetus* A. Rich.	Asteraceae	S	Qoraattii harree	043x
42	*Eleusine floccifolia* (Forssk.)Spreng.	Poaceae	H	Serdo, Akirma	027
43	*Erythrina brucei* Schweinf.	Fabaceae	T	Waleensuu	114
44	*Eucalyptus camaldulensis* Dehnh.	Myrtaceae	T	Bargamoo diimaa	023x
45	*Euclea divinorum* Hiern	Ebenaceae	S	Mi`eesssaa	060
46	*Euphorbia abyssinica* Gmel.	Euphorbiaceae	T	Adaamii	048x
47	*Ficus thonningii* Blume	Moraceae	T	Dambii	092
48	*Ficus vasta* Forssk.	Moraceae	T	Qilxuu	096
49	*Galiniera saxifraga* (Hochst.) Bridson	Rubiaceae	S	Mixoo fakkaata	074
50	*Galinsoga quadriradiata* Ruiz & Pavon	Asteraceae	H	Arama abbaa fidoo & booqee	063

Appendix 1 continued

51	*Galium aparinoides* Forssk.	Rubiaceae	H	Ukkaamsaa dinnichaa	006
52	*Gardenia ternifolia* Schumach. & Thonn.	Rubiaceae	S	Gambelloo	100
53	*Geranium arabicum* Forssk.	Geraniaceae	H	-	109
54	*Glycine wightii*(Wight & Arn.) Verdc.	Fabaceae	C	Hidda hantuutaa	032
55	*Grevillea robusta* R. BR.	Proteaceae	T	‘Giraavilliyaa’	070x
56	*Grewia ferruginea* Hochst. ex A. Rich.	Tiliaceae	S/T	Dhoqonuu	069
57	*Guizotia scabra(*Vis.)Chiov.	Asteraceae	H	Tuufoo	071
58	*Hyparrhenia dregeana* (Nees) Stent	Poaceae	H	Daggala(citaa)	053
59	*Hypoestes forskaolii (*Vahl*)* R.Sch.	Acanthaceae	H	dargu	007
60	*Inula confertiflora A. Rich.*	Asteraceae	S	Hartuu daalacha	052
61	*Jasminum abyssinicum* Hochst. ex DC.	Oleaceae	C	Hidda Ichilibe	055
62	*Jasminum grandiflorum*	Oleaceae	S	dagalee qinaaxxii	094
63	*Juniperus procera* Hochst. ex. Endl.	Cupressaceae	T	Gaattiraa habasha	115
64	*Justicia schimperiana* (Hochst. ex Nees) T. Anders.	Acanthaceae	S	Dhummuugaa	116
65	*Kalanchoe petitiana* A.Rich.	Crassulaceae	H	Bosoqqee	077
66	*Laggera crispate* (Vahl) Hepper & Wood	Asteraceae	H	Keskesa(harata abbaa hundee)	104
67	*Leucas martinicensis(*Jacq.)R.Br.	Lamiaceae	H	Boccuu fardaa/ ras kemer	057

Appendix 1 continued

68	*Lippia adoensis* Hochst. ex Walp.	Lamiaceae(verbenaceae)	S	Kusaayee	018
69	*Lolium perenne* L.	Poaceae	H	Gosa xaafii	030
70	*Maesa lanceolata* Forssk.	Myrsinaceae	S/T	Abbayyii	001
71	*Microlepia strigosa* F. Crispa Shishi	Dennstaedtiaceae	F	Karrolee	010
72	*Momordica foetida* Schumach.	Cucurbitaceae	C	Dallarra yaatuu/harege resa	090x
73	*Myrsine africana* L.	Myrsinaceae	S	Qacama	002
74	*Mytenus arbutifolia*(A.Rich) Wilc Zek	Celasteraceae	S/T	Qarxammee	025
75	*Nicandra physaloides* (L)Gaertn.	Solanaceae	H	Fooricaa	093
76	*Ocimum lamiifolium* Hochst.ex.Benth.	Lamiaceae	S	Q/michh/damakasee	068
77	*Olea europaea* L. subsp. *cuspidata* (Wall.exG.Don) Cif.	Oleaceae	T	Ejersa	011
78	*Olinia rochetiana* A. Juss.	Oliniaceae	S	Soolee	040
79	*Osyris quadripartita* Decn.	Santalaceae	S	Waatoo	054
80	*Otostegia fruticosa* (Forssk.) Schweinf. ex Penzig,	Lamiaceae	S	Ilillii adii(cingitii garraammii)	075
81	*Otostegia integrifolia* Benth.	Lamiaceae	S	Cingiitii	073
82	*Pavonia urens* Cav.	Malvaceae	S	incinni	041
83	*Pennisetum riparium* Hochst. ex A. Rich.	Poaceae	H	Migira	021x
84	*Pennisetum villosum*	Poaceae	H	Araddoo	044x

Appendix 1 continued

85	*Pentas lanceolata*(Forssk.) Defl.	Rubiaceae	S	Akka mixoo gerfecee	019
86	*Phoenix reclinata* Jacq.	Arecaceae	S	Meexxii	065
87	*Phytolacca dodecandra* L` Herit.	Phytolaccaceae	S	Handoodee	099
88	*Plantago lanceolata* L.	Plantaginaceae	H	Qorxoobbii	112
89	*Premna schimperi* Engl.	Lamiaceae	S	Urgeessaa	061
90	*Pseudognaphalium melanosphareum* (Sch.Bip.ex.A.Rich) Hilliard	Asteraceae	H	Yenib arrittii	012 [x]
91	*Pterolobium stellatum (*Forssk Brenan.	Fabaceae	S	Harangamaa	067
92	*Rhamnus prinoides* L` Herit.	Rhamnaceae	S	Geeshoo	022
93	*Rhamnus staddo* A.Rich.	Rhamnaceae	S	Qadiidaa	003
94	*Rhus vulgaris* Meikle	Anacardiaceae	S	Xaaxxessaa	008
95	*Ricinus communis* L.	Euphorbiaceae	S/T	Qobboo	005x
96	*Rosa abyssinica* Lindley	Rosaceae	S	Qaqawwee	004
97	*Rubus steudneri* Schweinf.	Rosaceae	S	Goraa/enjori	038
98	*Rumex nepalensis* Spreng.	Polygonaceae	H	Tuultii/mucha arba	045
99	*Rumex nervosus* Vahl	Polygonaceae	S	Dhangaggoo/Inbewacho	102
100	*Rytigynia neglecta* (Hiern.)	Rubiaceae	S	Mixoo	089
101	*Salvia nilotica* Jacq.	Lamiaceae	H	-	107
102	*Sida schimperiana* Hochst. ex Rich.	Malvaceae	S	Kottee harree/chifirigii	062
103	*Solanum incanum* L.	Solanaceae	H	Hiddi	084

Appendix 1 continued

104	Sparrmannia ricinocarpa (Ec/d. & Zeyh.) O. Ktze.	Tiliaceae	S	Akka qobboo firi qoree	046
105	*Sporobolus africanus* (Poir.) Robyns & Tournay	Poaceae	H	Murii	042
106	*Trifolium simense* Fresen.	Fabaceae	H	siddisa	024
107	*Vernonia amygdalina* Del	Asteraceae	S	Eebicha	016
108	*Vernonia auriculifera* Hiern.	Asteraceae	S	Reejjii	050
109	*Vernonia leopoldii (*Sch.-Bip.ex.Walp.)Vatke	Asteraceae	H	-	082
110	*Vernonia noveboracensis* (L.)Michx.	Asteraceae	S	Sookee gogorrii	015

Appendix 2. Quadrats and their characteristics

Quadrat	**Sample**	**Altitude(m)**	**Species no.**	**Latitude**	**Longitude**
1		2525m	30	08^0 58’ 072’’ N	038^0 02’190’’ E
2		2526m	14	08^0 58’ 078’’ N	038^0 02’ 201’’ E
3		2524m	17	08^0 58’090’’ N	038^0 02’ 266’’ E
4		2533m	13	08^0 58’ 084’’ N	038^0 02’ 227’’ E
5		2537m	12	08^{0}58’081’’ N	038^{0}02’229’’ E
6	1	2554m	9	08^0 58’ 072’’ N	038^0 02’ 231’’ E
7		2532m	12	08^{0}58’037’’ N	038^{0}02’237’’ E
8		2534m	13	08^0 58’ 091’’ N	038^0 02’ 243’’ E
9		2531m	16	08^{0}58’095’’ N	038^{0}02’249’’ E
10		2538m	15	08^0 58’ 082’’ N	038^0 02’ 242’’ E
11		2536m	13	08^{0}58’085’’ N	038^{0}02’240’’ E
12		2530m	12	08^0 58’ 088’’ N	038^0 02’ 244’’ E
13		2529m	12	08^{0}58’080’’ N	038^{0}02’239’’ E
14		2515m	10	08^0 58’ 063’’ N	038^0 02’ 228’’ E
15		2522m	14	08^0 58’ 066’’ N	038^0 02’ 237’’ E
16	2	2140m	18	08^0 58’ 505’’ N	037^0 49’ 891’’ E
17		2153m	18	08^0 58’ 496’’ N	037^0 49’ 891’’ E
18	2	2164m	20	08^0 58’ 480’’ N	037^0 49’ 869’’ E
19		2182m	19	08^0 58’ 459’’ N	037^0 49’ 853’’ E
20		2183m	16	08^0 58’ 433’’ N	037^0 49’ 818’’ E

Appendix:2 continued

21		2188m	20	08^0 58’ 421’’ N	037^0 49’ 815’’ E
22		2190m	18	08^0 58’ 410’’ N	037^0 49’ 808’’ E
23		2201m	13	08^0 58’ 397’’ N	037^0 49’ 801’’ E
24		2105m	16	08^0 58’ 412’’ N	037^0 49’ 807’’ E
25		2128m	13	08^0 58’ 416’’ N	037^0 49’ 813’’ E
26		2119m	11	08^0 58’ 419’’ N	037^0 49’ 825’’ E
27		2132m	12	08^0 58’434 ’’ N	037^0 49’ 821’’ E
28		2135m	11	08^0 58’ 417’’ N	037^0 49’ 828’’ E
29		2123m	12	08^0 58’ 440’’ N	037^0 49’ 831’’ E
30	3	2062m	13	08^0 59’ 428’’ N	037^0 49’ 492’’ E
31		2052m	14	08^0 59’ 413’’ N	037^0 49’ 458’’ E
32		2044m	12	08^0 59’ 396’’ N	037^0 49’ 430’’ E
33		2037m	17	08^0 59’ 396’’ N	037^0 49’ 415’’ E
34		2036m	10	08^0 59’ 390’’ N	037^0 49’ 420’’ E
35	4	2082m	14	08^0 59’ 786’’ N	037^0 49’ 224’’ E
36		2065m	19	08^0 59’ 825’’ N	037^0 49’ 277’’ E
37		2067m	18	08^0 59’ 809’’ N	037^0 49’ 304’’ E
38		2064m	10	08^0 59’ 825’’ N	037^0 49’ 266’’ E
39	5	2002m	13	08^0 59’ 411’’ N	037^0 49’ 401’’ E
40		2008m	16	08^0 59’ 422’’ N	037^0 49’ 408’’ E
41		2018m	14	08^0 59’ 431’’ N	037^0 49’ 413’’ E
42		2023m	14	08^0 59’ 430’’ N	037^0 49’ 420’’ E
43		2084m	11	08^0 59’ 508’’ N	037^0 49’ 345’’ E
44	6	2067m	14	08^0 59’ 797’’ N	037^0 49’ 365’’ E
45		2068m	15	08^0 59’ 790’’ N	037^0 49’ 389’’ E
46		2067m	16	08^0 59’ 761’’ N	037^0 49’ 437’’ E
47		2083m	18	08^0 59’ 744’’ N	037^0 49’ 376’’ E
48		2094m	13	08^0 59’ 544’’ N	037^0 49’ 549’’ E
49		2078m	14	08^0 59’ 612’’ N	037^0 49’ 414’’ E
50		2096m	13	08^0 59’ 621’’ N	037^0 49’ 425’’ E
51		2087m	12	08^0 59’ 546’’ N	037^0 49’ 501’’ E
52		2045m	17	08^0 59’ 556’’ N	037^0 49’ 571’’ E

Appendix 3: Community types with their plot size and number of species
Source: Survey data

Community Type	No of Plot	No of Species	Percentage
1	17	242	32.1%
2	5	62	8.2%
3	9	117	15.5%
4	9	141	18.6%
5	12	194	25.6%
Total	52	755	100%

Appendix 4: Percentage frequency of all species in the study area.

Species	No of quadrats	Total quadrats	Frequency (%)	Relative frequency (%)
Carrisa spinarum	29	52	55.8	3.8
Croton macrostachyus	28	52	53.8	3.7
Olea europaea	27	52	51.9	3.6
Calpurnea aurea	26	52	50	3.4
Pennisetum riparium	23	52	44.2	3.0
Premna schimperi	20	52	38.5	2.6
Vernonia auriculifera	20	52	38.5	2.6
Rhus vulgaris	19	52	36.5	2.5
Pterolobium stellatum	18	52	34.6	2.4
Andropogon abyssinicus	17	52	32.7	2.3
Albizia schimperiana	16	52	30.8	2.2
Asparagus africanus	16	52	30.8	2.2
Hypparhania dregeana	16	52	30.8	2.2
Cynodon dactylon	16	52	30.8	2.2
Maesa lanceolata	15	52	28.8	2.0
Sporobolus africanus	15	52	28.8	2.0
Mytenus arbutifolia	13	52	25	1.7
Rosa abyssinica	13	52	25	1.7
Euclea divinorum	13	52	25	1.7
Echinops longisetus	13	52	25	1.7
Acacia albida	12	52	23.1	1.6
Acacia dolichocephala	10	52	19.2	1.3
Clematis simensis	10	52	19.2	1.3
Euphorbia abyssinica	10	52	19.2	1.3
Grewia ferruginea	10	52	19.2	1.3
Rhamnus staddo	10	52	19.2	1.3
Rubus steudneri	10	52	19.2	1.3
Solanum incanum	10	52	19.2	1.3
Dovyalis caffra	9	52	17.3	1.2

Osyris quadripartita	9	52	17.3	1.2
Glycine wightii	9	52	17.3	1.2
Clausena anisata	8	52	15.4	1.0
Crassocephalum macropappum	8	52	15.4	1.0
Datura stramonium	8	52	15.4	1.0
Dodonaea angustifolia	8	52	15.4	1.0
Kalanchoe petitiana	8	52	15.4	1.0
Myrsine africana	8	52	15.4	1.0
Acacia sieberiana	7	52	13.5	0.9
Cordia africana	7	52	13.5	0.9
Berula erecta	7	52	13.5	0.9
Hypoestes forskaolii	7	52	13.5	0.9
Lippia adoensis	7	52	13.5	0.9
Olinia rochetiana	7	52	13.5	0.9
Plantago lanceolata	7	52	13.5	0.9
Vernonia amygdalina	7	52	13.5	0.9
Eucalyptus camaldulensis	6	52	11.5	0.8
Acacia mearnsii	6	52	11.5	0.8
Galinsoga quadriradiata	6	52	11.5	0.8
Guizotia scabra	6	52	11.5	0.8
Acokanthera Schimperi	5	52	9.6	0.7
Aeschynomene abyssinica	5	52	9.6	0.7
Bidens prestinaria	5	52	9.6	0.7
Cynoglossum coeruleum	5	52	9.6	0.7
Ficus vasta	5	52	9.6	0.7
Laggera crispate	5	52	9.6	0.7
Sida schimperiana	5	52	9.6	0.7
Trifolium simense	5	52	9.6	0.7
Bersama abyssinica	4	52	7.7	0.5
Bidens pilosa	4	52	7.7	0.5
Capparisa tomentosa	4	52	7.7	0.5
Cyathula uncinulata	4	52	7.7	0.5
Jasminum abyssinicum	4	52	7.7	0.5
Nicandra physaloides	4	52	7.7	0.5
Ocimum lamifolium	4	52	7.7	0.5
Rytigynia neglecta	4	52	7.7	0.5
Brucea antidysenterica	3	52	5.8	0.4
Budleja polystachya	3	52	5.8	0.4
Geranium arabicum	3	52	5.8	0.4
Pavonia urens	3	52	5.8	0.4
Pennisetum villosum	3	52	5.8	0.4
Phoenix reclinata	3	52	5.8	0.4
Rumex nervosus	3	52	5.8	0.4

Salvia nilotica	3	52	5.8	0.4
Vernonia noveboracensis	3	52	5.8	0.4
Achyranthes aspera	2	52	3.8	0.3
Celtis africana	2	52	3.8	0.3
Colutea abyssinica	2	52	3.8	0.3
Cupressus lusitanica	2	52	3.8	0.3
Dichrocephala integrifolia	2	52	3.8	0.3
Erythrina brucei	2	52	3.8	0.3
Galium aparinoides	2	52	3.8	0.3
Microlepia strigosa	2	52	3.8	0.3
Otostegia integrifolia	2	52	3.8	0.3
Phytolacca dodecandra	2	52	3.8	0.3
Argemone mexicana	1	52	1.9	0.1
Cirsium vulgare	1	52	1.9	0.1
Clutia abyssinica	1	52	1.9	0.1
Commelina benghalensis	1	52	1.9	0.1
Cyphostemma Cyphopetalum	1	52	1.9	0.1
Echinops kebericho	1	52	1.9	0.1
Eleusine floccifolia	1	52	1.9	0.1
Ficus thonningii	1	52	1.9	0.1
Galiniera saxifrage	1	52	1.9	0.1
Gardenia ternifolia	1	52	1.9	0.1
Grevillea robusta	1	52	1.9	0.1
Inula confertiflora	1	52	1.9	0.1
Jasminum grandiflorum	1	52	1.9	0.1
Juniperus procera	1	52	1.9	0.1
Justicia schimperiana	1	52	1.9	0.1
Leucas martinicensis	1	52	1.9	0.1
Lolium perenne	1	52	1.9	0.1
Momordica foetida	1	52	1.9	0.1
Otostegia fruticosa	1	52	1.9	0.1
Pentas lanceolata	1	52	1.9	0.1
Pseudognaphalium melanosphareum	1	52	1.9	0.1
Rhamnus prinoides	1	52	1.9	0.1
Ricinus communis	1	52	1.9	0.1
Rumex nepalensis	1	52	1.9	0.1
Sparmannia ricinocarpa	1	52	1.9	0.1
Vernonia leopoldii	1	52	1.9	0.1

Appendix: 5 DBH class and density of tree species per hectare.

No	Species Name	DBH Classes (cm)				
		2-10	10-20	20-30	30-40	>=40
1	*Albizia schimperiana*	10.6	5.8	3.8	0.0	0.0
2	*Calpurnia aurea*	15.9	14	2.9	0.0	0.0
3	*Cordia africana*	0.0	0.0	3.8	7.7	1.9
4	*Croton macrostachyus*	14.4	22.1	4.8	2.4	0.0
5	*Ficus vasta*	0.0	0.0	0.0	1.4	1.9
6	*Maesa lanceolata*	13.9	5.3	0.0	0.0	0.0
7	*Olea europaea*	14.1	8.7	12.4	2.9	0.0
8	*Acacia albida*	8.7	4.3	4.8	1.4	0.0
9	*Acacia dolichocephala*	5.7	7.2	1.9	0	0.0
10	*Acacia mearnsii*	3.0	4.8	2.8	1.0	0.0
11	*Euphorbia abyssinica*	0.0	0.0	1.9	3.5	0.0
12	*Acacia sieberiana*	0.5	3.5	0.0	0.0	0.0
13	*Olinia rochetiana*	0.0	5.8	1.9	0.0	0.0
14	*Eucalyptus camaldulensis*	0.0	0.0	1.9	6.7	0.0
15	*Celtis africana*	1.4	5.3	0.0	0.0	0.0
16	*Cupressus lusitanica*	0.0	0.0	0.0	1.4	0.0
17	*Erythrina brucei*	0.0	0.0	0.0	1.4	0.0
18	*Ficus thonningii*	0.0	0.5	0.0	0.0	0.0
19	*Grevillea robusta*	0.0	0.0	0.5	0.0	0.0
20	*Juniperus procera*	0.0	0.0	0.0	0.5	0.0
	Total	88.2	87.3	43.4	30.3	3.8
	% DBH distribution	34.8	34.5	17.2	12	1.5

Appendix 6: Stem number and height classes of tree species of the study area.

Species Name	Height classes(m)				
	2_7	7.1_12	12.1_17	17.1_22	>=22
Albizia schimperiana	15	16	11	0	0
Calpurnia aurea	30	20	8	0	0
Cordia africana	3	0	14	10	1
Croton macrostachyus	40	33	12	6	0
Ficus vasta	0	0	1	4	2
Maesa lanceolata	27	28	0	0	0
Olea europaea	30	35	14	0	0
Acacia albida	13	4	15	8	0
Acacia dolichocephala	8	12	8	0	0
Acacia mearnsii	5	6	10	3	0
Euphorbia abyssinica	2	5	5	0	0
Acacia sieberiana	0	5	4	0	0
Olinia rochetiana	7	9	0	0	0

Eucalyptus camaldulensis	0	0	0	8	9
Celtis africana	6	8	0	0	0
Cupressus lusitanica	0	0	3	0	0
Erythrina brucei	0	1	2	0	0
Ficus thonningii	0	1	0	0	0
Grevillea robusta	0	0	0	1	0
Juniperus procera	0	0	0	1	0
Total	186	183	107	41	12
% height distribution	35.2	34.5	20.2	7.8	2.3

Appendix 7: Plant families with their genera and species distribution percentage in the study area

Family	No of Species	%species	No of Genera	%Genera
Asteraceae	16	14.5	11	11.2
Fabaceae	13	11.8	9	9.2
Amaranthaceae	2	1.8	2	2.1
Apocynaceae	2	1.8	2	2.1
Poaceae	8	7.3	7	7.1
Papaveraceae	1	0.9	1	1.0
Asparagaceae	1	0.9	1	1.0
Apiaceae	1	0.9	1	1.0
Melianthaceae	1	0.9	1	1.0
Simaroubaceae	1	0.9	1	1.0
Buddlejaceae	1	0.9	1	1.0
Capparidaceae	1	0.9	1	1.0
Ulmaceae	1	0.9	1	1.0
Rutaceae	1	0.9	1	1.0
Rununculaceae	1	0.9	1	1.0
Euphorbiaceae	4	3.6	4	4.1
Commelinaceae	1	0.9	1	1.0
Boraginaceae	2	1.8	2	2.1
Cupressaceae	2	1.8	2	2.1
Vitaceae	1	0.9	1	1.0
Solanaceae	3	2.7	3	3.1
Sapindaceae	1	0.9	1	1.0
Flacourtaceae	1	0.9	1	1.0
Myrtaceae	1	0.9	1	1.0
Ebenaceae	1	0.9	1	1.0
Moraceae	2	1.8	2	2.1
Rubiaceae	5	4.5	5	5.1
Geraniaceae	1	0.9	1	1.0
Proteaceae	1	0.9	1	1.0
Tiliaceae	2	1.8	2	2.1
Acanthaceae	2	1.8	2	2.1
Oleaceae	3	2.7	3	3.1

Crassulaceae	1	0.9	1	1.0
Lamiaceae	7	6.4	6	6.1
Myrsinaceae	2	1.8	2	2.1
Dennstaedtiaceae	1	0.9	1	1.0
Cucurbitaceae	1	0.9	1	1.0
Oliniaceae	1	0.9	1	1.0
Santalaceae	1	0.9	1	1.0
Malvaceae	1	0.9	1	1.0
Arecaceae	1	0.9	1	1.0
Phytolaccaceae	1	0.9	1	1.0
Plantaginaceae	1	0.9	1	1.0
Rhamnaceae	2	1.8	1	1.0
Anacardiaceae	1	0.9	1	1.0
Rosaceae	2	1.8	2	2.1
Polygonaceae	2	1.8	2	2.1
Celasteraceae	1	0.9	1	1.0
Total	110	100%	98	100%

Source: Survey data

Appendix: 8 TWINSPAN output

```
           0100000224041515124110123333331212222422133444433450
           1803927483862215016034585120458607124379937645796912
 Echi.kebe 4---------------------------------------------------
 Eleu.floc 1---------------------------------------------------
 Loli.pere 1---------------------------------------------------
 Pent.lanc 1---------------------------------------------------
 Pseu.mela 3---------------------------------------------------
 Rham.prin 2---------------------------------------------------
 Rici.comm 3---------------------------------------------------
 Gali.apar 4-----3---------------------------------------------
 Vern.nove 4---2----------------1------------------------------
 Rosa.abys 6453333444435---------------------------------------
 Arge.mexi ------3---------------------------------------------
 Inul.conf ------2---------------------------------------------
 Micr.stri 2-------------2-------------------------------------
 Maes.lanc 72435534533--34------32-----------------------------
 Jasm.abys -332---------------------------2--------------------
 Lipp.adoe 2-22---2--3----------12-----------------------------
 Rham.stad 62---324-2---3------223-----------------------------
 Acac.mear 2---312----------56---------------------------------
 Hypo.fors 3-------2---4-4--3-2----------------2---------------
 Myrs.afri 6----42----34----2---3--------------------------4---
 Olin.roch ---44--2--45----5-----------------------------5-----
 Rhus.vulg 43-233223--4243----4--1---------32-------24--3------
 Juni.proc -----------------6----------------------------------
 Eryt.bruc -----------------4-6--------------------------------
 Bide.pres ---3---------4------54---------------4--------------
 Rubu.steu ---2-----23-324-4-------3------------5-3------------
 Just.schi --------------------2-------------------------------
 Trif.sime 56--------------4--------------------------5-5------
 Vern.amyg 3----2----3------35-2-----------------------------5-
 Osyr.quad --3-3-------32-2-------------3----------2-2----2----
 Bide.pilo --------------52----3------------4------------------
 Aspa.afri -2-111-1---13--2----1-----4----1211----32-----------
```

```
Cirs.vulg  ----------------------3-----------------------------
Gali.quad  -----2-------24---2------------4------------------2-
Pavo.uren  ---2-----------2-------------------4----------------
Rume.nepa  ----------------------3-----------------------------
Spar.rici  ----------------------2-----------------------------
Olea.euro  233-22445---34343--3-32355-----2-4-32--------4--355-
Euca.cama  3-4--------------4----------------545---------------
Cras.macr  24-------------1---3---32----------------------33---
Nica.phys  --------2-3------------------6----------------2-----
Penn.ripa  25632----3-----3-----322-44533-56434---3-----4--5---
Penn.vill  ----------------------4--4-3------------------------
Colu.abys  2------------------------------------------------2--
Hypa.dreg  -2--2-----264--24-----242---343------4-------5----5-
Andr.abys  2-2----1-2---2--------13323222----6-25----2---------
Dich.inte  1-------------------------------------2-------------
Glyc.wigh  --2-222----------------2---------2--2-3------------4
Beru.erec  2---2------3--------------------2-34----------3-----
Euph.abys  -----------6-----4----5666358--------------------6--
Rume.nerv  -------4--------5----------------------------------5
Cyno.dact  --4--------------54545-3553--4-----656-4---4--------
Budl.poly  -----------------33---------------------4-----------
Ocim.lami  --1--------------------2-----------1--2-------------
Vern.auri  -22-3------3-34--244---2--44-63-----3----2-5---45-4-
Myte.arbu  3---3---3-------3---2--3-------4-354----535---------
Cari.spin  -222-32-3----4354-353--23-6--4-2-33------335453-434-
Cupr.lusi  ---3------------------------------------6-----------
Clem.sime  ---2-2----3-----4--5----------------35---4---3-----3
Acok.Schi  ---------3--4-----------2---------------------4-3---
Clau.anis  ---------3-----3----------------3222--3-2-----------
Kala.peti  ---------------2-22------3-2-------3-----2------2---
Dovy.caff  ---53-----------3--2-------------------3--54----33--
Sida.schi  -----------------------1---2-1-1----------1---------
Spor.afri  ---3-3-2-33-------34---------------5--2-----5545-24-
Plan.lanc  -------34------------5----------------------4--24--3
Leuc.mart  -------------------------------2--------------------
Otos.inte  ------------------2---------------------3-----------
Dodo.angu  ------------4--2---2----------3---2------3----3----3
Vern.leop  ------------4--------------------------------------4
Acac.albi  ---------35--------------46-3-3--------4--454-2-3---
Aesc.abys  2-------------------------------21-------3-------2--
Cyno.coer  --------------------2---5---------------3----------2
Gali.saxi  --------------------------------3-------------------
Datu.stra  --------1---2---5-------------1--------3---2------24
Albi.schi  --------63-------------33------635656475---564------
Eucl.divi  ---------4---------33----------252553---4-34-5------
Echi.long  ---4-------------------3---353-33---4---3-55--3----3
Lagg.cris  --2-------------------------------1----14-4---------
Calp.aure  -------3-4-----3-2-32-----2-4546434344--63447-4-44-4
Otos.frut  ----------------------------------3-----------------
Acac.sieb  ---------------------------3--433-2-----45----------
Acac.doli  -----------------------2---6535--43---------554-----
Cyat.unci  --------------------------3-3--------------1---3----
Achy.aspe  ------------------------------2-------3-------------
Clut.abys  -----------------------------------1----------------
Comm.beng  -----------------------------------5----------------
Salv.nilo  ----------2---------------------------------2------2
Capp.tome  --------------4-------------------------3-4-------4-
Guiz..scab -------------------------3-4-----3------44-------4--
Gera.arab  ------------1-------------------------2---4---------
Crot.macr  -------------3---------455634555343--454565455345545
Prem.schi  ------------------55---3-----4-33333--5-353553434--3
Celt.afri  ------------------------------------3-3-------------
Pter..stel --------------344------33--3------45-----5544635554-
```

```
Grew.ferr  -------------------------4--2--22---23---4--3--4---2
Sola.inca  -----------------------2-24-----1-2-----2---2-34---3
Bruc.anti  ----------------2-------------------------------3-2-
Cord.afri  ----------4--------6--------------------------5-6655
Grev.robu  ----------------------------------------6-----------
Phoe.recl  ---------------------------------2-----3-------3----
Ficu.thon  -----------------------------------------5----------
Momo..foet -----------------------------------------4----------
Ryti.negl  ------------------------------------3-3-----34------
Bers.abys  ------------------------------------3--2--3----3----
Phyt.dode  -------------------------------------6--------6-----
Gard.tern  ----------------------------------------------3-----
Cyph.cyph  -----------------------------------------------5----
Jasm.gran  ------------------------------------------------4---
Ficu.vast  -------------------------------------------6----8665
```

Appendix 9: Endemic plant species of the study area (IUCN category and Habit: LC = Least Concern, T = tree, S = shrub, H and H = herb)

Species	**Family**	**Habit**	**IUCN category**
Erythrina brucei	Fabaceae	T	LC
Kalanchoe petitiana	Crassulaceae	H	LC
Lippia adoensis	Verbenaceae	S	LC
Vernonia leopoldii	Asteraceae	S	LC
Crassocephalum macropappum	Asteraceae	H	LC
Inula confertiflora	Asteraceae	S	LC