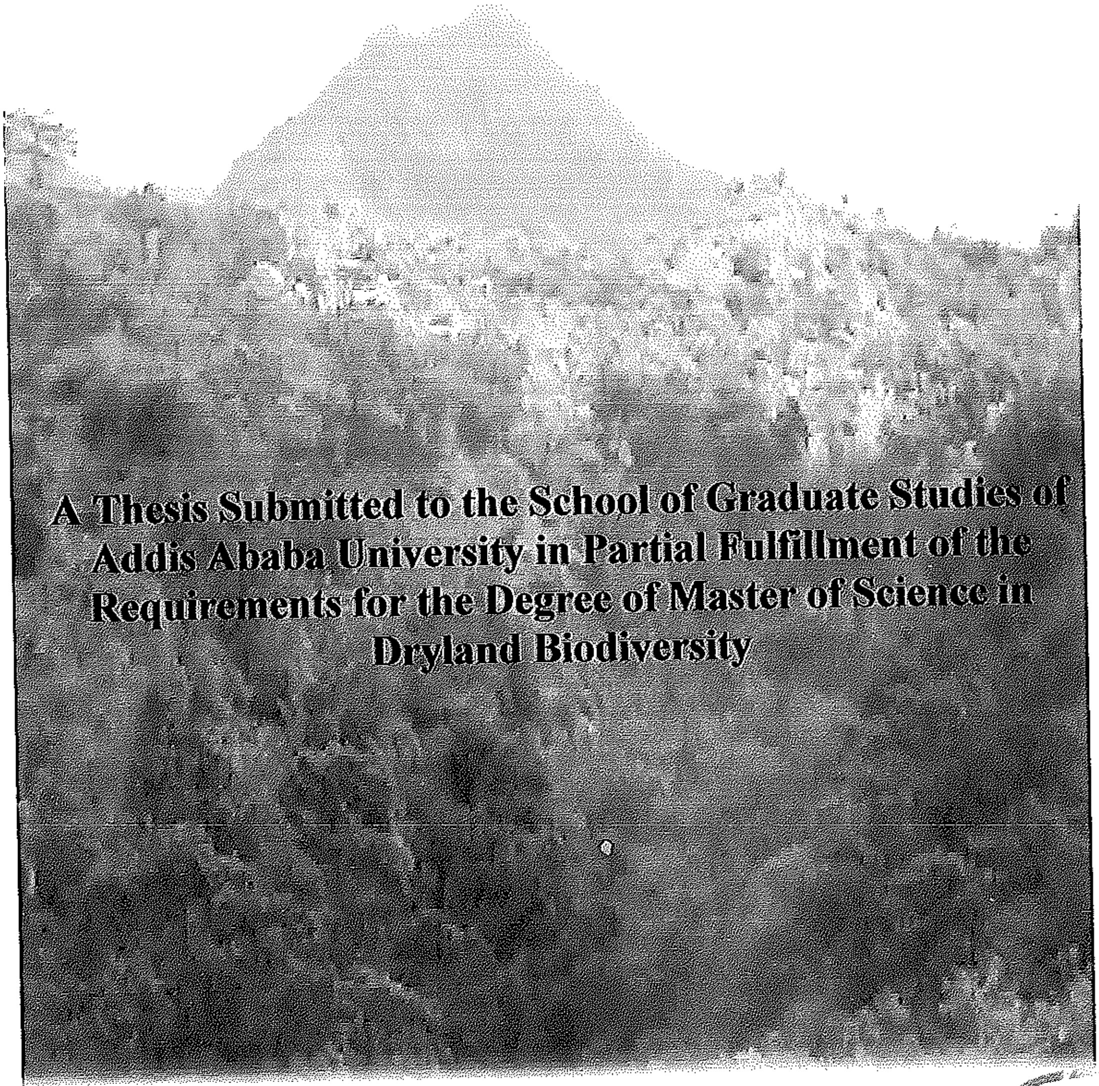
The Floristic Composition of Natural Vegetation of Abaya – Hamassa, Wolayta Ethiopia



By

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The Floristic Composition of Natural Vegetation of Abaya-Hamassa Wolaytá, Ethiopia

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Dryland Biodiversity

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Abstract

The present study was carried out in the rift valley of southern Ethiopia, which is generally characterized by arid and semi-arid climatic conditions. Studies in the natural vegetation of the area were conducted between October 24, 2003 and June 28, 2004. The vegetation and environmental data were collected from 55 quadrats (400 m^2) of eight selected sites. The purpose of this study was to investigate the floristic diversity of natural vegetation of Abaya Hamassa in the rift valley of southern Ethiopia. In this paper, the major issues addressed include floristic diversity, vegetation description, community type identification and study of communities – environment relationships. During the study, percentage cover abundance of each species was estimated and taken in 55 quadrats. Later the percent cover values of all recorded plant species was converted into the modified Braun-Blanquet 1-9 scale. The environmental parameters altitude, slope, aspect, pH, electrical conductivity, total nitrogen and soil texture (% sand, % clay and % silt) were measured for all quadrats. A total of 315 plant species representing 198 genera and 59 families were identified. All the environmental and vegetation data were analized with TWINSPAN computer program. Six plant community types were obtained and described. Community-environment relationship was assessed based on some soil physical and chemical properties data collected from 55 quadrats. Among the environment parameters altitude is negatively correlated with sand and clay. There was significant correlations between total nitrogen with sand.

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Table of Contents

Pages

List of Tables

List of Figures

List of Appendix

1. INTRODUCTION

1.1 Background

The topographic diversity of Ethiopia that emanates from the diverse geologic history has resulted in the formation of a multitude of agro-ecological zones and sub-zones suited for various farming systems and supporting diverse vegetation types. With its wide range of ecological types from arid lowlands in the east to rainforests in the west and high-altitude afro-alpine vegetation in the central highlands, Ethiopia is rich in biodiversity. According to Ensermu Kelbessa (personal communication), Ethiopia has about 6000 species of higher plants of which nearly 10.5% are endemic to the country. Thus, Ethiopia has got a large stock of biodiversity. This may be partly due to the over all diversity of the habitats and ecosystems. If there are abrupt changes in habitats and ecosystems in altitude, slope, moisture gradients, temperature, rainfall and drainage, diversity may change abruptly with short distances (Munishi, 1998). These abrupt changes in site conditions accompanied by changes in the characteristics of soils, microclimatic conditions and thus result in variation of distribution, structure and composition of vegetation (Lind and Morrison, 1974; Munishi, 1998). This diversity is, however, severely threatened by environmental degradation, particularly in the densely populated areas, with regard to the tree and shrub flora in the highlands; the indigenous species are largely replaced by a few exotic species (Azene Bekele - Tesemma *et al.*, 1993).

Natural vegetational climaxes have disappeared or been reduced to isolated pockets (Rowland, 1993). Over use, including heavy cutting of trees for firewood has caused widespread degradation of natural vegetation resources. Desertification is a constant threat. The expansion of agriculture into forested regions and the impoverishment of forests from intensive harvests, fires and grazing have reduced the forested area of the earth (Woodwell, 2001).

Historical sources indicate that Ethiopia was a heavily forested country, with about 35 - 40 % of the total area covered by dense forests (EFAP, 1994). According to FAO (1980) the natural forests of Ethiopia occur generally between the altitudes 600 m a.s.l. to 3000 m a.s.l. With forests for the most part occuring in the altitudinal range of 1400 – 2600 m a.s.l., though they may extend to both lower and higher altitudes according to climatic factors specially rainfall. At the beginning of the 1990's the total area of forest and woodland resources was estimated to be about 27.5 million ha. of which the total area of natural high forests, woodlands, bushlands and plantations have been estimated at 2.3, 5, 20, and 0.2 million ha respectively (EFAP, 1994).

In Ethiopia as a whole, the area covered by natural vegetation is being reduced at a faster rate. The forest vegetation cover of Ethiopia has been declining continuously. In the early 1950's, 16% of the land area of Ethiopia was covered with forests (EFAP, 1994). In the early 1980's the forest coverage was reported at 3.6% and in 1989 it was estimated at only 2.7% (EFAP, 1994). At present, most of the remaining forests of Ethiopia are confined to the south and southwest.

In Ethiopia, environmental degradation and desertification have been taking place for hundreds if not thousands of years. Trees have been cleared to open up land for agriculture. Ethiopia's natural vegetation has been affected by agricultural activities for at least 5,000 years, and widespread deforestation began around 2,500 years ago (Hurni, 1985; cited in WCMC, 1991). In addition, Ethiopia has the 1st largest population of livestock in Africa, thus grazing pressure has increased the rate at which tree and shrub species are becoming scarcer (Azene Bekele - Tesemma *et al.*, 1993). Demel Teketay (2001) showed that the accelerated deforestation becomes even more alarming when one considers the subsequent environmental degradation characterized by dwindling biodiversity, loss of fertile soil and degradation of water bodies.

The natural ecosystems of Ethiopia which are important centers of biodiversity and endemism are under considerable pressure from the rapidly expanding population. For example, 30 years ago the woodland in the rift valley was continuous (Zerihun Woldu and Mesfin Tadesse, 1994; cited in Zerihun Woldu *et al.*, 1999).

Ethiopia's woodland resources are under severe pressure as a consequence of population growth and an associated need for agricultural and pastoral lands. Zerihun Woldu and Mesfin Tadesse (1990) pointed out that degradation of woodland is most remarkable in the central rift valley where woodlands were reduced to 4 percent of the original extent within a time span of 50 years. Ensermu Kelbessa *et al.* (1992) also suggested that much of the woody vegetation especially in the northwestern part of the country covered by *Combretum - Terminalia* woodland has been removed due to the intensification of agriculture.

Felling of trees for various domestic uses and making charcoal have decimated the vegetation and most of the land is now cultivated leaving the woodland fragmented into small patches (Zerihun Woldu *et al.*, 1999). It is thus doubtful that forests covered 40% of the country in historical times, as has been stated by FAO (1980) and many other institutions. Still with only 2.7% of the country forested, and 0.9% of the original coniferous forest (*Podocarpus* and *Junperus*), 11% of the original broad-leaved forests and 7.6% of the original savanna woodlands remaining, the present situation is very alarming (WCMC, 1991).

Vegetation study in the Ethiopia rift valley area is not new. White (1983) classified the Ethiopian rift valley area as *Cenchrus ciliaris* grassland. Zerihun Woldu and Mesfin Tadesse (1990) studied the vegetation status and recovery potential of degraded areas of the lake region. Until early this century general surveys of descriptions of Ethiopian vegetation were presented by foreign travellers passing through the country on a mission other than floristic (Tamrat Bekele, 1993). Vegetation types in Ethiopia has been described and classified based on physiognomic criteria. Few vegetation studies have also been based on floristic composition. Few of these include : vegetation of the Erer - Gota plain, Harar (Beals, 1969), Menagesha Suba state forest, Shewa (Sebsebe Demissew, 1980), Jemjem forest, Sidamo (Hailu Sharew, 1982), grassland vegetation on the central plateau of Shewa (Zerihun Woldu, 1985), Harenna forest, Bale (Lissanework Nigatu, 1987) and forests of the central plateau of Shewa (Tamrat Bekele, 1993).

According to Sebsebe Demissew (1998), Ethiopian vegetation is generally divided into nine major types: the desert and semidesert scrubland, lowland semi-evergreen forest, *Acacia-Commiphora* woodland, *Combretum-Terminalia* woodland, evergreen scrub, dry evergreen montane forest and grassland, moist evergreen montane forest, Afro-alpine and subafroalpine, and the riparian and swamp vegetation. Among these, desert and semi-desert scrub, *Acacia-Commiphora* woodland and evergreen scrub are found in arid and semi-arid areas of the rift valley system (Kibrom Tekle, 1998; Sebsebe Demissew, 1998).

The vegetation of arid and semi-arid land varies from dry woodland and grass savannas to desert plant communities. Most of what we see today is the result of man intervention through burning, grazing, clearing for agriculture or controlling the tsetsefly (Joss *et al.*, 1986). Drylands represent a sizable portion of the earth's potentially arable land surface. Roughly 12 million ha of Subsahara Africa is arid and semi-arid and within these, are to be found 40 million people and 80 million livestock (Joss *et al.*, 1986).

According to the FAO (2000) classification, Ethiopia is one of the thirty-six dryland developing countries in the world. These countries have most of their land belonging to the arid and semi-arid areas defined as having 100-600 mm annual rainfall. The sensitivity of drylands to climatic fluctuation was dramatically illustrated by several droughts that affected Ethiopia in 1888-1892 (Pankhurst, 1966) and more recently in 1984/5 and 2001/2 (personal observation). The drylands of Ethiopia are reportedly biodiversity rich (Tewolde Brhan Gebre Egziabher, 1990; Blench and Marriage, 1999) and any vegetation change may result in species decline or loss.

According to Amaha Kassahun (2002), Ethiopia has a total land area estimated at about 112.3 million ha pastoralism and agro-pastoralism predominant production systems in drylands of Ethiopia mainly in arid and semi-arid agro-ecologies. Natural forests and woodlands in dryland regions are capable of providing multiple benefits to people living in these areas. However, in many dryland regions forest management has not been practiced on a sustainable basis (Ffolliott *et al.*, 1995). The following Table presents the climate, vegetation and land use patterns in low land tropical Africa.

Table 1. Climate, vegetation and land use patterns in lowland tropical Africa

Subclimate	Vegetation types/livestock	Land use patterns
Desert	Contracted; camels, goats, some sheep, rarely cattle	Grazing (nomadism), no cultivation without irrigation
Very arid and arid	Diffuse shrubland and open bushland, perennial grasses; camels, goats, sheep, some cattle (zebu)	Grazing (nomadism), virtually no rainfed cultivation
Semi-arid	Bushland and open woodland, perennial grasses; cattle, sheep, goats, rarely camels	Grazing (nomadism and settled pastoralists), some farming (millet, sorghum, cowpea)
Dry subhumid	Woodland, savanna, grassland, cropland (light tsetse infestation); cattle (zebu), sheep, goats	Cropping of millet, sorghum, cowpea, groundnut, sweet potato, pigeonpea; settled animal husbandry; pasture sowing and reseeding possible
Subhumid	Woodland, savanna, grassland, cropland (neavy tsetse infestation in woodland and savanna); some cattle, sheep goats	Cropping of sorghum, maize, sugar cane, banana, rice, yam, cassava, cotton, tobacco; limited animal husbandry (pasture sowing and reseeding)
Humid	Forest, woodland, savanna, cropland; perennial tsetse infestation (riverine); taurine cattle and dwarf sheep and goats	Cropping as above; timber production; restricted animal production
Very humid	Rain forest; heavy tsetse infestation; taurine cattle and dwarf sheep and goats	Oil palm, coconut, hevea; timber production; restricted animal husbandry

Source: FAO, 1981b

Information on vegetation may be required to help solve ecological problems such as input to environmental impact statements; to monitor management practices or to provide the basis for prediction of possible future changes (Martin and Paddy, 1992). Appropriate policies, planning procedures, implementational methods, managerial and extension programs are required to apply vegetation conservation on a sustainable basis in dryland regions. A necessary background to an appreciation and proper use of this information includes recognition of what characterizes dryland environments and the constraints that these environments place on the practice of vegetation conservation (Ffolliott *et al.*, 1995).

The present study area, which is located in the southern rift valley of Wolayta zone, is generally characterized by arid and semi-arid climatic conditions. Although there are some woodland and bushland resources in the study area, there is no information available on the condition of these resources. The vegetation of the area is under threat by the combined forces of resource exploitation and forest degradation. These include activities like frequent burning, clearing and grazing. As human activities alter landscapes and ecological processes on larger scales, the need for improved management and conservation of land, water, and marine resources will require greater understanding of ecosystem composition, structure and function. In order to suggest on the use of these resources on a sustainable basis, a clear understanding of these resources is deemed to be important. Therefore, proper understanding of vegetation structure and floristic composition is crucial for sustainable use of resources for our present and future walfare and proper management. This is due to the fact that knowledge about vegetation composition and structure provides insight about the potential of plant community to succession after disturbance.

1.2 Objectives

1.2.1 General Objective

The major objective of this thesis was to:
Study the floristic composition and environmental variables and assess the extent of human impact on the natural vegetation.

1.2.2 Specific Objectives

The specific Objectives of the study were to:

i. compile species list of the natural vegetation

ii. Analyze the relationship between environmental variables and the identified community types

iii. Document the environment variables such as altitude, slope, aspect and

iv. Recommend conservation measures for the vegetation in the area.

1.3 Research questions

i. What are the major plant communities?

ii. What are the dominant and common species?

iii. What are the apparent correlations of the occurrence of the various types of vegetation with topography?

iv. What communities are natural or semi-natural?

v. What will be the diversity, abundance of plant species in the study area?

2. LITERATURE REVIEW

2.1 Plant Community Concept

A plant community is an organized complex having typical composition (floristic aspect) and structure (morphological aspect) those results from the interaction through time. It is not a mere aggregation of plants. A community is a sociological unit of any rank, occupying a territory and having a characteristic composition and structure. One of the characteristics of a community is its physiognomy, the way it appears. Physiognomy is largely a product of the predominant life forms of the organisms composing the community (Cain and Castro, 1959).

Martin and Paddy (1992) defined the plant community as the collection of plant species growing together in a particular location that show a definite association or affinity with each other. Plant association is characterized by combinations of different characteristic species, having a defined floristic composition in that association than the other association (Andreucii *et al.*, 2001). The idea of association implies that certain species are found growing together in certain locations and environments more frequently than would be expected by chance. The reason that certain species grow together in a particular environment will usually be because they have similar requirements for existence in terms of environmental factors such as light, temperature, and water drainage and soil nutrients. They may also share the ability to tolerate the activities of animals and humans such as grazing, burning, cutting or trampling (Martin and Paddy, 1992).

The concept of the plant community include: the organismal concept, the community as superorganism; the individualistic concept (Gleason 1926), the community as a changeable mixture of individualistically distributed plant species and the concept of population structure (Whittaker, 1970), the community as a system of interacting species and vegetation as a complex population pattern.

2.2. Theoretical View Points on the Nature of the Plant Community

Regarding the structure of communities two different views have been presented in the past. The first community concept is the organismic (the discrete community) concept or community unit theory. This concept is also known as Clements view point. The second plant community concept is the individualistic (community continuity or continuum) concept. This concept is also called the Gleason's view point of plant community.

The Clementesian school of thought considers communities as discrete units that can be identified and classified. The Clementesian School, understands communities as superorganisms that have its own life and structure as well as its own temporal and spatial limits (Chapman and Reiss, 1992; Brown and Lomolino, 1998). The Gleason's concept viewed plant communities as continuous entities (Lewis and Tayler, 1979). Gleason (1926 and 1939) viewed all plant species distributed as a continuum. He argued that species respond individually to variation in environmental factors and those factors vary continuously in both space and time. Whittaker (1975) viewed that plant communities change gradually along complex environmental gradients, so that no distinct associations of species can be identified. However recently Collins *et al.*, (1993) have proposed a "hierarchical continuum" concept of the community patterns, which reconcile the two views. These community concepts are briefly discussed as follows.

2.2.1. The organismic (discrete) community concept

This concept states that plant communities are clearly recognisable and definable entities, which repeated themselves with great regularity over a given region of the earth's surfaçe (Clements, 1916 and 1928). The discrete community unit theory implies the existence of distinct communities (Walter, 1971). The distinctive vegetation of each area represents a distinct community, which is separated by sharp vegetational transition from other communities (Ricklefts, 1997).

Species belonging to a community are closely associated with one another implying, the ecological limits of distribution of each species will coincide with the distribution of the community as a whole (Burbour *et al.*, 1987). The discrete community concept predicts that the distribution of species along certain gradients, groups of species or communities would replace one another (Shipley and Keddy, 1987). Within each grouping, most species have similar distributions and the end of one group coincides with the beginning of another (Shipley and Keddy, 1987).

For discrete communities to exist it must show discontinuities over the continuous environmental template (Robert, 1987). Within this community unit concept, the plant community is the basic unit, and may be represented by a group of relatively homogenous samples classified based on floristic similarity into a hierarchical table (Palmer and Van Staden, 1992). Moreover, this view regards communities as having a degree of internal organizations, which jointly modify the environment with sharp delimitation from other environments. Therefore, the existance of such communities could attribute to the competition and exclusion of other less competitive ones by few dominant species (Roberts, 1987 and Paul, 1993).

2.2.2. The individualistic (continuum) concept

Plant species respond individually to variation in environmental factors (Gleason, 1926 and 1939) and those factors vary continuously in both space and time. Every species has a different distribution or tolerance range and abundance. The assemblage of plants growing in an area is not only the result of environmental conditions but also species migration. The success of these species depends on the combination of environmental factors at that site and the tolerance ranges of the invading species. Gleason argued that the range of permutations of combinations of environmental factors together with the different tolerance ranges of the species, would always give a different combination and abundance of species (Martin and Paddy, 1992).

The individulistic concept implies the gradual distribution pattern in plant communities. This may be due to many environmental factors like moisture, temperature, light, soil condition (Ricklefts, 1990). In this concept communities replace one another (Cloessen *et al.*, 1994) and distribution of one species within each group has similarity and the end of one group becomes the beginning of another.

The continuum concept suggests that plant community change (in their composition) gradually along the complex environmental gradients and hence identification of distinct community association is not possible (Collins *et al.*, 1993). The distribution centers and species range boundries are widely scattered so that no groups of species would aggregate to form a distinct community unit (Burbour *et al.*, 1987). Rather each species has its own physiological tolerance limit to environmental variables and the environmental variables would also fluctuate and vary across partial scales (gradients).

Both concepts (discrete concept and continuum concept) emphasize environmental factors giving little attention to the modification effect of the vegetation and their subsequent influence on the pattern of community (Roberts, 1987).

As indicated by Shipley and Keddy (1987), the dichotomy should be avoided since both hypotheses do not exhaust the natural community patterns but they are competing rather than complementing as well as dealing with a special case of dynamical system (Roberts, 1987). Therefore, the need for a hypothesis that incorporates the two different views with regard to the existence of natural patterns of a community became crucial. Collins *et al.*, (1993) developed the hierarchical continuum concept, with regard to the distribution patterns of plant communities. The hierarchical continuum concept can be viewed as an attempt to incorporate both hypotheses and the pattern of community organization may take hierarchical structure.

Thus, the hierarchical continuum concept assumes that some species will have a wider distribution, others localized, and still some others will have a much restricted distribution across the sample area. Hence, the distribution pattern and abundance of species assumes a hierarchical structure where species with wider, intermediate and restricted distribution ranges show some kind of hierarchies than a continuum or discrete.

2.3. Species Diversity

Biodiversity refers to the variety of life forms, the genetic diversity they contain, and the assemblage they form (U.S. National Research Council, 1992). According to Mclean and Ivimer-Cook (1973), Kumer (1981), Paul (1993) species diversity can be viewed in terms of species richness, species endemism, evenness and taxonomic diversity. Biological systems, whether tundra, forests, savannahs, grasslands, deserts, lakes, rivers, wetlands, coastal communities or marine ecosystems are functionally complex and this complexity is associated in often obscure ways, with the diversity of their component species (U.S. National Research Council, 1992).

Global biodiversity has fluctuated through geologic time as evolution has added new species and extinction has taken them away (Jablonski, 1991). Diversity depends on such processes like ecological, evolutionary, geological and biochemical and the interactions between them (Huston, 1994). In view of this, geologically older areas like the tropics would have high species diversity (Ewuisie, 1980).

Most estimates suggest that there are about 250, 000 species of vascular plants in the world (U.S. Nation Research council, 1992). Approximately two-thirds of these are found in the tropics. The new world tropics (lately discovered parts of the world such as in Latin America Ecuador, Peru, and Colombia) are particularly rich in species. One-sixth of the earth's diversity of plant life about 45, 000 species can be found in Latin America.

The diversity of higher plant species increases as one move from the poles to the equator. According to Groombridge (1992), between 40 and100 tree species may occur on one hectare of tropical moist forests in Latin America, compared to 10-30 per hectare in forest in eastern North America. Estimates of the total number of ferns, gymnosperms and angiosperm species in Ethiopia and at a global level as summarized from Groombridge (1992) is given in Table 2.

Table 2. Estimates of the number of ferns, gymnosperms and angiosperm species of Ethiopia and the world.

Plant groups	Ferns	Gymnosperms	Angiosperms
In the world	12,000	500	250,000
In Ethiopia	100	3	6,000-7,000

Source: Groombridge 1992.

According to Reaka-Kudla, *et al.*, (1997) the number of species currently described is 1.4 million. Current estimates of the total number of species run from 10-1000 million.

2.3.1. Distribution patterns of species diversity

A direct gradient in overall taxonomic diversity is associated with latitude. Species diversity decreases from low latitude to higher latitude. That is diversity is low towards the poles and high towards the tropics (Simpson, 1964; Tramer, 1974; Wilson, 1974; Rabinovich and Rapoport, 1975; Stevens, 1989; Currie, 1991; Pagel *et al.*, 1991; Willing and Sandlin, 1991; Dennis, 1992).

The effect of latitudinal gradients vis-a-vis competition, mutualism, predation, patchiness, environmental stability, environmental predictability, productivity, area, number of habitats, ecological time, evolutionary time and solar energy in species diversity have been tested in different mechanisms (Pianka 1966; Brown, 1988; Rohde, 1992; Rosenzweig, 1992; Jablonski, 1993; Colwell and Hurtt, 1994). Rohde (1992) concluded that "greater species diversity is due to greater "effective" evolutionary time (evolutionary speed) in the tropics. Rosenzweig (1992) state that latitudinal gradients arise because the tropics cover more area than any other zone and their greater area stimulates speciation and inhibits extinction.

A trend of increasing species diversity with decreasing latitude applies across many groups of organisms on land (Stevens, 1989). More species live in a given area in the tropics than in similar -sized areas at higher latitudes. The pattern has been attributed to trees, mammals, birds, reptiles, amphibians and insects (Latham and Ricklets, 1993; Simpson, 1964; Cook, 1969; Kiester, 1971), among others.

In the case of islands diversity gradients, remote or small islands may have fewer species than larger islands, which is closer to the main lands (MacArthur and Wilson, 1967; Whittaker *et al.*, 2001). The possible explanations for the island pattern of species diversity are based on the equilibrium between immigration and extinction (MacArthur and Wilson, 1967; Brown and Lomolino, 1998; Lomdino and Weiser, 2001).

Patterns of diversity on elevational gradients, with diversity shows lower near the foot and higher at mid-slope, since altitudes experience double gradients of temperature and rainfall besides its isolation from the surrounding area (Brown and Lomolino, 1998). Most interest in the relationship between species diversity and altitude for terrestrial systems has concerned small spatial scales. Here, two broad patterns are, a decline in species richness from low to high altitudes and a peak of richness at mid-altitudes (Lawton *et al.*, 1987; Wolda 1987; McCoy 1990). This is mainly due to the double gradient of temperature and precipitation. Therefore, it is two types of gradients that act one against the other and produce a favorable environment at intermediate level of altitude.

Broad gradients in species diversity with changing longitude have been reported. These include increases in insect, avian, and mammalian species diversity towards the west of North America (Tramer, 1974; Pagel *et al.*, 1991; Danks, 1993 and 1994), an increase in water bird species richness towards the east of Southern Africa (Gullet and Crowe, 1986).

Diversity of many taxa decreases along the length of peninsulas (Simpson, 1964; Cook, 1969; Brown, 1987). Diversity at many taxonomic levels also tends to decrease from continents to islands or within continental areas with increasing distance from potential sources (MacArthur and Wilson, 1967).

In arid lands, water availability imposes severe constraints on species diversity. Precipitation is characterized by unpredictability in time and space as well as by low total amounts (Noy-Meir, 1973). Semi-arid ecosystems differ from true arid areas in structure and in the rate and regulation of ecosystem processes.

Biodiversity, reflected in species richness, is moderately high in semi-arid regions and declines with increasing aridity for most taxa (Shmida, 1985 and O'Brien, 1993).

On the small scales, the diversity is divided into alpha diversity, beta diversity and gamma diversity components (Whittaker, 1960 and 1972). Alpha diversity is within area diversity, measured as the number of species occuring within an area of a given size (Huston, 1994). It, therefore, measures the richness of a potentially interactive assemblage of species. Beta diversity designates the degree of species change along a given habitat or physiogeographic gradient (Whittaker, 1960). It is measure between-area diversity. Beta diversity is normally represented in terms of the similarity index or of a species turn over rate.

Gamma diversity is also a measure of within-area diversity; however it usually refers to overall diversity within a large region (Cornell, 1985), and it is dealing with biodiversity at the landscape level (Noss, 1983; Franklin, 1993). Alpha and gamma diversity pertain to the number of taxa at local and regional special scales respectively, and their units are number of species or other suitable measures of diversity. They are thus inventory diversities (Whittaker, 1977). However, as indicated by some authors, the distinction among alpha, beta and gamma diversity is vague (Whittaker *et al.*, 2001). Hence, Whittaker *et al.*, (2001) prefer to use local, landscape and macro-scale instead of alpha, beta and gamma diversity respectively.

2.3.2. The importance of species diversity

The presence of a large number of species of animals and plants is very important because their physiological differences furnish various sources of food, clothing, shelter and medicine for man. The presence of a great number of species with different structures, different chemical compositions, and different life spans form one of the most important bases of life for humans throughout our planet (Reaka-Kudla *et al.*, 1997).

The diversity of plant life is an essential underpinning of most of our terrestrial ecosystems. Humans and most other animals are almost totally dependent on plants directly or indirectly as a source of energy through their ability to convert the sun's energy through photosynthesis. Worldwide tens of thousands of species of higher plants, and several hundred lower plants are currently used by humans for a wide diversity of purposes as food, fuel, fiber, oil, spices, industrial crops, medicines and as forage and fodder for domesticated animals (WWF, 1994).

Beyond such direct values, biological diversity provides ecological services that are more difficult to calculate with precision. Living organisms are an important part of the processes that regulate the earth's atmospheric, climatic, hydrologic, and biogeochemical cycles.

It is esier to comprehend the ecological services that biological diversity provides more locally in protecting watersheds cycling nutrients, combating erosion, enriching soil, regulating water flow, trapping sediments, mitigating pollution, and controlling pest populations. Another extremely valuable way in which biodiversity service human society is as an indicator of ecological changes.

Finally, ethical and aesthetic concerns direct us to respect, and strive toward rational stewardship of, the world" heritage of biological resources. The non economic, intangible and inherent values of biological diversity take us beyond the traditional realm of the science, into the realm of the arts and humanities, language and history religion and philosophy. These varied modes of human perception and expression have a fundamental stake in the fate of biological diversity, and must contribute to the determination of its fate.

2.3.3. Loss of biodiversity

Recent estimates suggest that more than half the habitable surface of the earth has already been significantly altered by human activities (Hannah and Bowles, 1995). It has also been suggested that we are on the verge of mass extinctions of species (Myers, 1979).

In the past, when human activities slowly altered limited areas of the earth's surface, the rate of local extinctions was barely distinguishable from the natural background rate. Now we may be losing species at a rate of 1000 to 10,000 times greater than the background rate (Wilson, 1988). As Robinson (1988) notes, "we are destroying irreplaceable species on an unprecedented scale without regard for their potential economic, aesthetic or biological significance". Even conservative estimates of species loss rates suggest that unless current trends are reversed, more than one-quarter of the earth's species may vanish in the next 50 years (Raven, 1988; Wilson, 1989; Reid and Miller, 1989; Ehrlich and Wilson, 1991).

The current loss of biodiverity has several causes (McNeely *et al.*, 1990; Soule, 1991). The direct destruction, conversion or degradation of ecosystems results in the loss of entire assemblage of species. Over exploitation, habitat disturbance, pollution and the introduction of exotic species accelerate the loss of individual species within communities or ecosystems. The loss of species through changes in land use has occurred frequently and is irrevocable (Solbring, 1991). Reduction in population size, fragmentation of populations, and alterations in the relative abundance of species are increasingly common phenomena with profound ecological implications.

2.4. Techniques for Analyzing Vegetation Data

Multivariate techniques have been developed to study the complex nature of plant communities. Techniques of summarizing and arranging the available informations are necessary since it is the basis for comparing these informations with environmental and other factors affecting the composition of vegetation (Greig-Smith, 1983). In aiming for a detailed floristic vegetation description, two major approaches can be distinguished. These are the relevé analysis for classification and the continuum analysis for ordinator (Mueller-Dombis and Ellenberg, 1974). These two approaches toward vegetation study are based on different concepts of the essential nature of vegetation. Classification aims at grouping individual stands into categories. The stands those are similar to one another form one class, which is separated from other classes that also consist of similar stand (Mueller-Dombois and Ellerberg, 1974). This method emanated from the belief that vegetation is composed of certain distinct and fairly discrete plant communities (the concept of community unit theory) (Whittaker, 1962 and 1967; Shimwell, 1971). The properties common to a group of similar stands in a class are then abstracted to serve as description of that class.

In contrast, an ordination is believed to have developed from the concept of vegetation as a continuum. It aims at portraying the individuality of each stand. This is done by demonstrating the similarity or dissimilarity of all stands to one another (Kershaw, 1973; Mueller-Dombois and Ellenberg, 1974).

In spite of their differences, both methods compete in obtaining a thorough description of a restricted vegetation region or widely distributed vegetation information.

Stands sampled for classification can be subjected to ordination, while stands sampled for an ordination can be classified. The difference in approach lies in the degree of entitation and the sample distribution. The broader degree of entitation is applied in continuum analysis, while the finer degree of entitation is applied in classification. The two methods are truly complementary only where the degree of entitation is the same and where the sampling intensity in continuum analysis is increased over that of the relevé analysis (Mueller-Dombois and Ellenberg, 1974).

In the past, although there has been considerable controversy between the applications of these techniques by ecologists, it is now generally recognized that both classification and ordination techniques could be appropriately applied to the same vegetation data and that the choice between the two approaches depends on the ecological question to be answered (Greig-Smith, 1983).

Similarly, Zerihun Woldu and Backeus (1991) in the study of shrubland vegetation of western Shewa, and Tamrat Bekele (1994) in his studies on remnant afromontane forests of the central plateau of Shewa have employed both techniques.

2.4.1. Classification

Classification relies on defining a set of classes in which members of the same class and those of different classes with the intention that similarity is a matter of degree. Thus, similar properties shared by different classes and other properties that are not shared commonly serve to identify that particular class. Classification begins with the assumption that communities consist of discrete entities. Classification involves arranging stands into classes, the members of each class having in common one or more features setting them apart from the members of other classes (Greig-Smith, 1983).

Classification can be hierarchical or non-hierarchical. Non-hierarchical classifications divide samples into a number of clusters. Groups have no joint structure. The aim of such technique is to produce the most efficient groups regardless of the route by which they are derived (Greig-Smith, 1983). If homogeneity of a group is of a prime importance in the application process, the non-hierarchical techniques are best fit.

Hierarchical classification techniques define relationships among the clusters. Samples having the same properties are arranged into classes and the classes at any level are subclasses of classes at higher level (Pielou, 1969). Hierarchical classification technique is further divided into two strategies, which are divisive and agglomerative strategies. In a divisive strategy the population is progressively subdivided into groups of diminishing size, while in an agglomerative strategy, a hierarchy may be built up by fusing individuals progressively into groups of increasing size until the whole population is merged into a single group (Greig-Smith, 1983). Similarly, there is a choice between monothetic strategy, which is based on a single attribute and polythetic strategy, which is based on a number of attributes.

The variety of hierarchical classification techniques may be summed up into three groups' monothetic divisive, polythetic divisive and polythetic agglomerative (Mueller-Dombois, 1974; Greig-Smith, 1983).

Monothetic divisive techniques begin with the entire sample in a single group. On the other hand, polythetic divisive classification techniques utilize information on all species. It begins with all samples together in a single cluster and successively divides the samples into a hierarchy of smaller and smaller clusters until finally, each cluster contains only one sample or some specified small number of samples (Dingby and Kempton, 1994). Polythetic agglomerative classification technique also uses information on all species, beginning with each sample in a cluster with a single number and agglomerates these in a hierarchy of larger and larger cluster until finally a single cluster contains all the samples (Dingby and Kempton, 1994).

2.4.2. Ordination

Ordination produces groups from the concept that vegetation is continuous (the continuum concept). It does not produce distinct groups, which can be classified instead it shows the interrelationship among species that are believed to be controlled by environmental gradient (Kershaw, 1973). Ordination aims at representing the individuality of each stand. It enables to obtain information on both continuity and discontinuity of the data studied as well as to recognize the number of possible clusters and their shapes (Goodall, 1973; Kershaw, 1973).

The success of ordination method depends on the use of appropriate variety of environmental variables (Begon *et al.*, 1996). It provided some hypothesis to be tested about the relationships between community composition and environmental factors (Chapman and Reiss, 1992). Results obtained by ordination emphesize the occurrence of predictable association of species under particular set of environmental variables and their common trend, which are most important in sorting out a group (Begon *et al.*, 1996).

3. MATERIALS AND METHODS

3.1 The Study Area

The study area is located in between Wolayta and Gamo-Gofa Zones at 6° 27.404' N - 6° 37.368' N and 36° 44.042' E - 36°52.169' E, which is located at about 450 km from southeast of Addis Ababa. It is located to the east of the western escarpment of the southern part of the Rift Valley and to the west and north east of Lake Abaya in the Southern Nations, Nationalities and Peoples Region.

The elevation of the study area ranges from 1184 m a. s. l. at the coast of Lake Abaya to 1410 m a. s. l. at Wanke Derya. The elevation decreases towards the Lake by forming tiers in a long distance. The topography of the study area is rugged and ranges from the steep slope at the escarpment of the Rift Valley to nearly flat surfaces around the coastal strip of Lake Abaya. The drainage pattern follows the general topographic orientation from west to east. Small rivers and streams rising from Wolayta and Chencha highlands drain to Lake Abaya and Lake Chamo. Some of these rivers are Hamassa, Bilate, Guracha, Bonge, Zegre and other smaller streams.

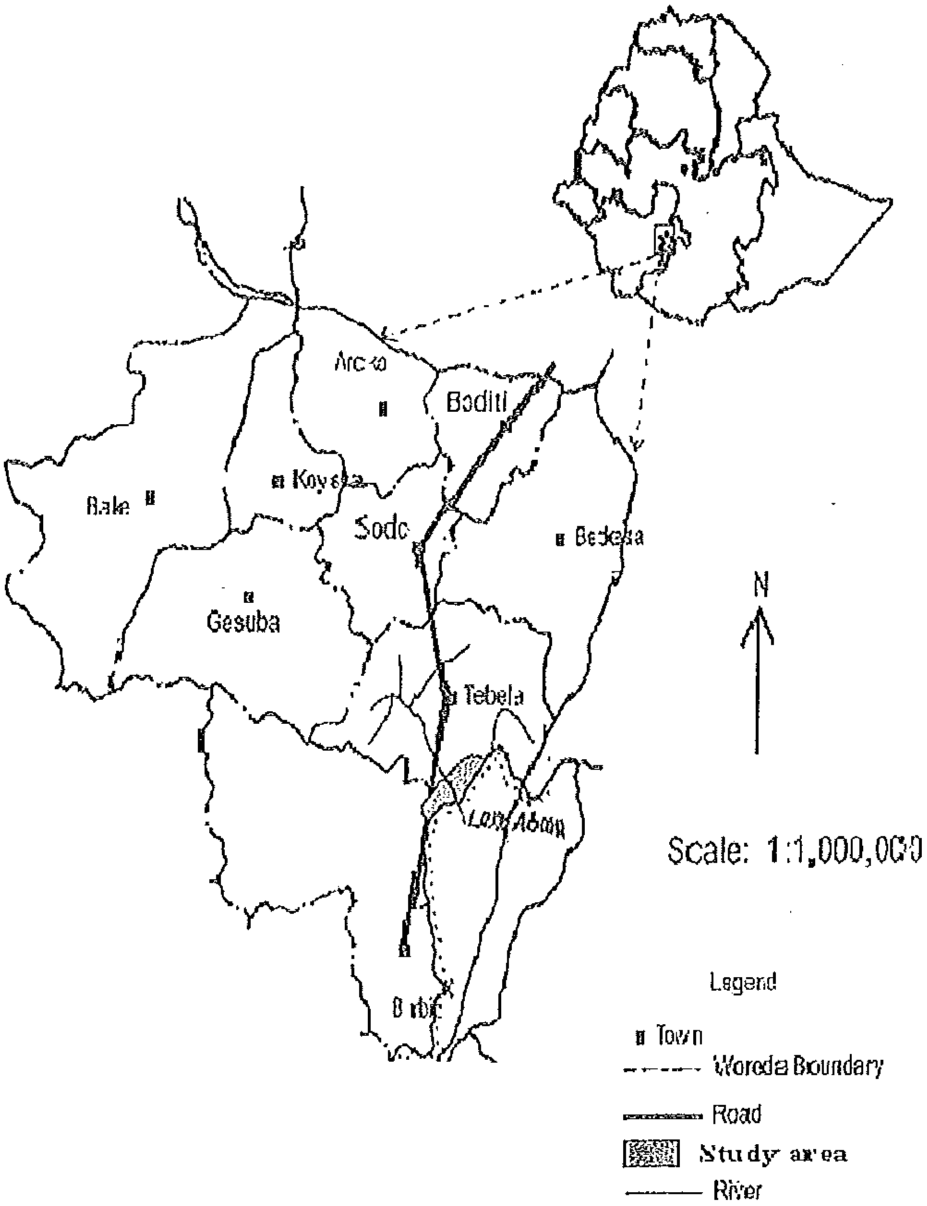

Figure 1. Location map of the study area (Wolaita Zone and Boreda Woreda)
Source: N.O.Z/DPED (2001)

3.2 Geology

The oldest known rocks in Ethiopia are of Precambrian origin (Mohr, 1971) and these are over 600 million years old (Ethiopian Mapping Agency, 1988). There are large exposures of pre-cambrian rocks in Ethiopia forming an as yet undifferentiated group known variously as the crystalline Basement, the Basement complex, or merely the Basement. The Basement complex is exposed in the peripheral regions of the country, and underlies all other more recent rocks such as occurs especially in the central and eastern parts of Ethiopia. It consists of a complex of metamorphic rocks of many different grades and types in some of which the original sedimentary or igneous character is still discernible (Mohr, 1971).

The basement of the southern part of the country, which is gneisses predominant, has been strongly metamorphosed (FAO, 1980). In the Lake Chamo basin faulting accompanied by wide spread volcanic activity lead to the formation of basaltic lava. To the north of Lake Chamo, Lake Abaya occupies the bottom of a large area of internal drainage. West of Lake Abaya rises the Gughe Mts, the remnant of a huge trap series volcano. It is notable that the throw of the faults west of Lake Abaya is down to the west, warping and tilting down to the east having contained the Lake in its basin (Mohr, 1971).

The soils along the floor of the rift valley and Lake Abaya are alluvial of Hare stream (Vaukasinovic, 1969) and Colluvial materials and lacustrine deposits of the Pleistocene are common to Lake Abaya (Mohr, 1971). Therefore, the soils of the area around the floor and Lake Abaya can be categorized as Fluvisols of the FAO/UNESCO revised Legend (1990).

3.3 Climate and Vegetation

3.3.1 Climate

The climate of the study area is generally characterised by arid and semi-arid climatic conditions. In the rift valley areas, a common climatic feature is that evaporation exceeds precipitation and hence annual water deficit.

According to information obtained from Wolayta Zone Agricultural Office, average annual rainfall of the study area ranges from 650 to 800 mm. Rainfall is bimodal occurring from March to May (short rain) and June to September (long rain). The mean monthly temperature of the area is between 22 to 28°C.

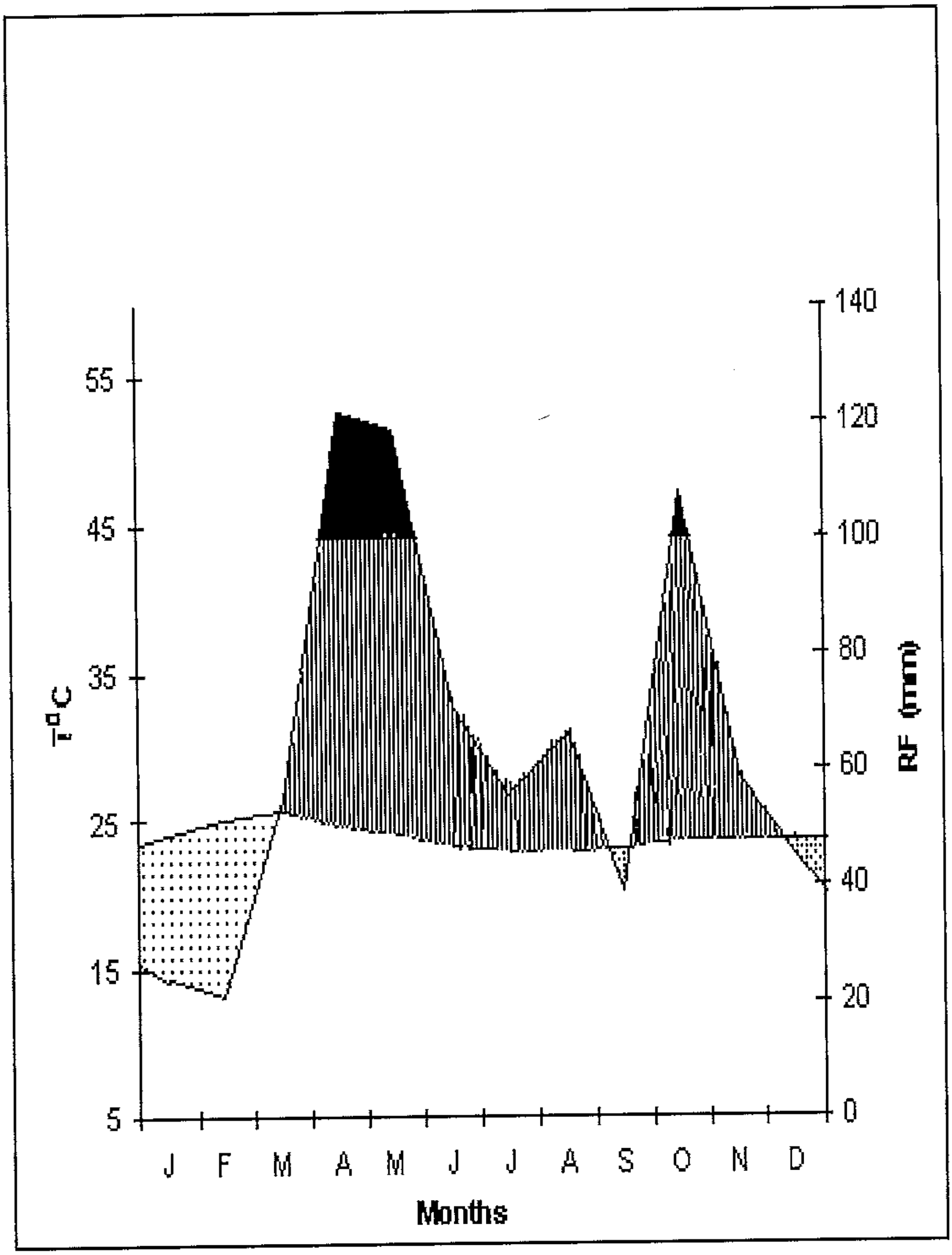

Fig 2. The Climadiagram for Mirab Abaya (mean temperature in °C and rain fall in mm for the years 1994-2003)

Source: National Metrological Services Agency (NMSA), (1994-2003)

3.3.2 Vegetation

Vegetation is the sum total of plants covering an area. It may be a forest with its trees, under shrubs, and herbs and the forest floor with mosses, fungi and lichens. It may consist of plants growing in marshes, or of algae submerged in water, or of the sparsely spaced cacti, sagebrush etc of the desert, or of the crustlike growth of lichens on others with bare rocks (Weaver *et al.*, 1980).

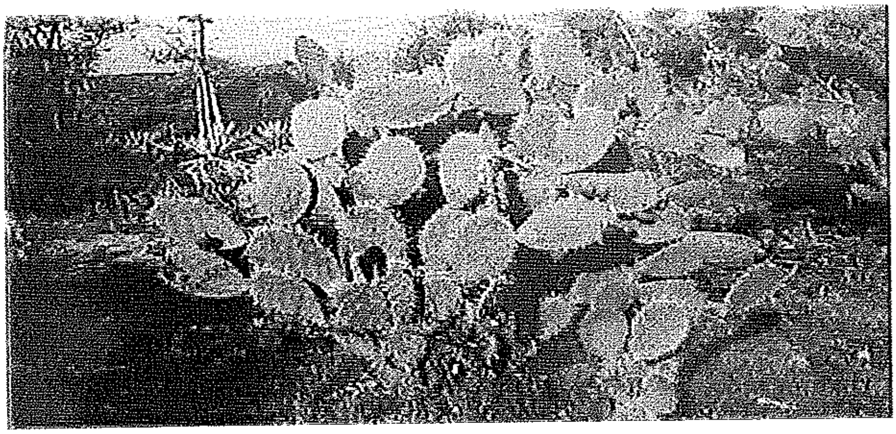

Figure 3. Cacti (*Opuntia ficus-indica*), arid and semi-arid species

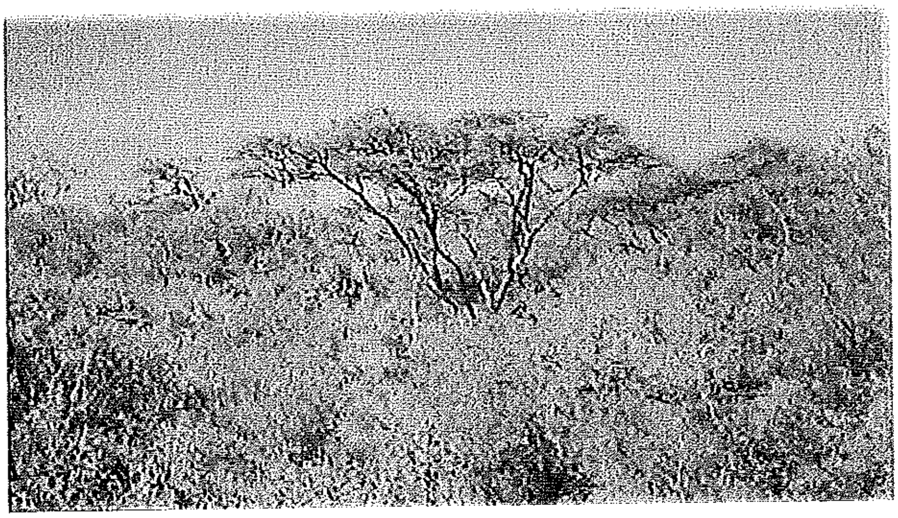

Figure 4. Riverine vegetation of Hamassa river bank

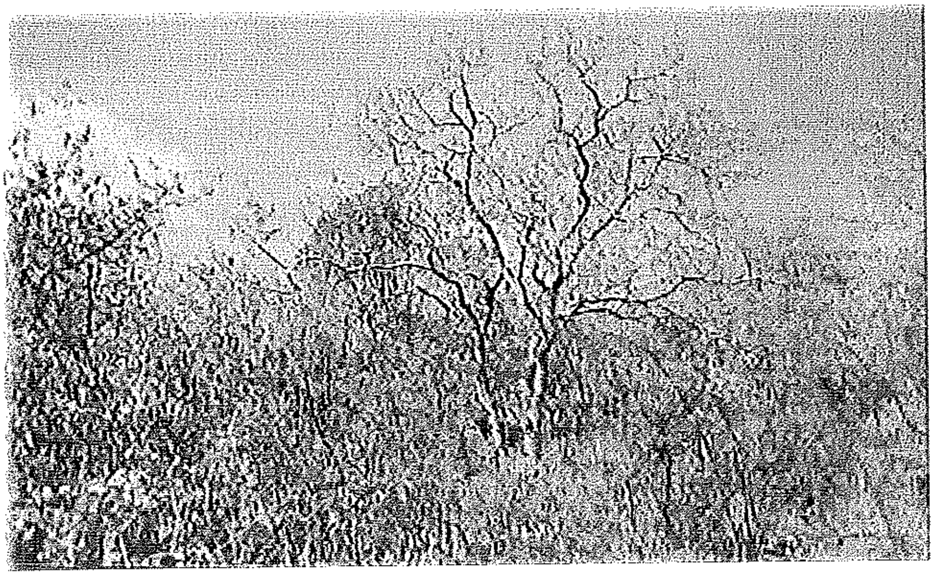

Figure 5. Riverine vegetation of Hamassa river bank

The vegetation types of the arid and semi-arid regions in Ethiopia include *Acacia* woodland, bushland and tickets, and open grasslands (Coppock, 1994). White (1983), classified the vegetation of east Africa on the basis of endemism. White categorized the vegetation of Ethiopia under the Sudanian Regional Center of Endemism, Somalia-Mas sai Regional Center of Endemism, Afromontane Regional Center of Endemism and Afro Alpine Archipelago-like Regional Center of Endemism. According to White's classification the present study area is found in the Somalia-Mas sai Regional Center of Endemism. But based on the broad categorization of Zerihun Woldu (1999) and EPA/TGE (1992), the vegetation in the study area is mainly small - leaved deciduous woodland. *Acacia-commiphora* woodland is found mainly between altitudes of 500-1900 m a. s. l. and an averaged annual temperature of 18°C to 27°C and rainfall between about 410-820 mm (Ensermu Kelbessa *et al.*, 1992). This woodland area has traditionally been grazing land (Ensermu Kelbessa *et al.*, 1992; Zerihun Woldu, 1999).

Figure 6. ***Acacia tortilis*** **and associated species in Abaya Hamassa study area**

3.4 Population and Land Use

According to the (CSA, 1999-2004), the population of Wolayta Zone was 1363555 (CSA, 1999) and 1583233 (CSA, 2004) and that of the Boreda Abaya Woreda was 116224 (CSA, 1999) and 134545 (CSA, 2004). The total population of the two regions is 1,717778 (CSA, July 2004). Within these 5 years, in two regions the population increased by 237999 (Table 3).

Table 3. Population size by sex, area and density in Wolayta Zone and Boreda Abaya Woreda from July 1999 to July 2004

Areas	Year	Male	Female	Total	Area km^2	Density $/km^2$
Wolayta Zone	In July 1999	674377	689178	1363555	4537.53	300.506
	In July 2000	695661	710967	1406628	4537.53	309.9986
	In July 2001	717294	732983	1450277	4537.53	319.6182
	In July 2002	739030	755110	1494140	4537.53	329.2849
	In July 2003	761000	777347	1538347	4537.53	339.03
	In July 2004	783307	799926	1583233	4537.53	348.92
Boreda Abaya Woreda	In July 1999	58019	58205	116224	1322.04	87.9
	In July 2000	59675	60013	119826	1322.04	90.6
	In July 2001	61630	61836	123466	1322.04	93.4
	In July 2002	63461	63669	127130	1322.04	96.2
	In July 2003	65303	65508	130811	1322.04	98.9
	In July 2004	67171	67374	134545	1322.04	101.8

Source: CSA (Central Statistical Authority), Statistical Abstracts 1998, 1999, 2000,2001, 2002 and 2003.

The alarming population increase obviously leads to an increase in the demand for natural resources, including arable land, water, wood for construction and energy. The increase in population size, urban development, and expansion of commercial and subsistence farming has exerted considerable influence on woodland vegetation in the rift valley region of Ethiopia (Zerihun Woldu and Mesfin Taddesse, 1990).

The majority of the population depends on subsistence rainfed agriculture and irrigation is rarely practiced. Both crop production and animal husbandry are important land uses practiced in the study area. Major annual crops are maize, cotton, and sorghum; while livestock production include cattle, goat, sheep and donkey. Livestock population of the four adjacent districts (woredas) is presented in Table 4.

Table 4. Number of livestock population by type of animals in four woredas, which are surrounding the study areas

Woredas	All Livestock							
	Cattle	**Sheep**	**Goats**	**Horses**	**Asses**	**Mules**	**Poultry**	**Beehives**
Damot Weyde	91851	16899	18029	-	6593	-	126548	3958
Humbo	53631	4445	27903	-	2761	-	89418	2955
Mirab Abaya	27827	3302	16030	191	679	104	32309	1925
Dale	166142	19492	17248	-	5425	-	205397	10716

Source: Ethiopian Agricultural Sample Enumeration, 2001/2002 (1994 E.C.)

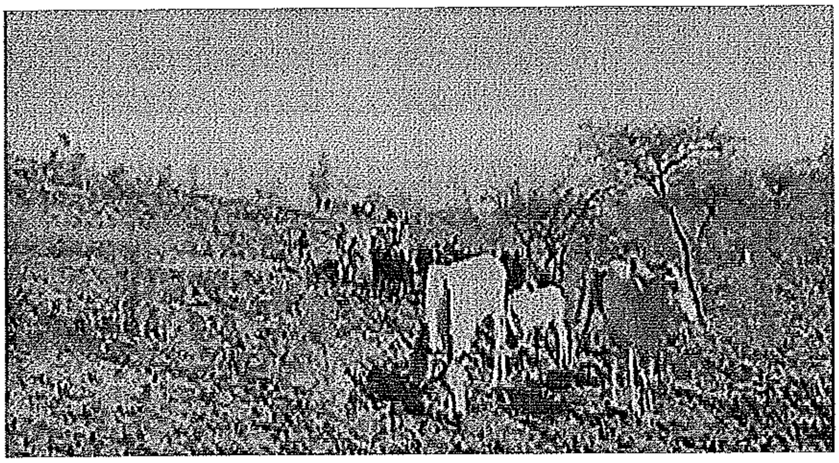

Figure 7. Overgrazing and highly degraded area (Heavy grazing and overstocking have changed many areas into degraded areas).

In many dry areas there is competition between various forms of land use which are to a large extent mutually exclusive.

In the past animal husbandry was the dominant production system. However, for the last few decades much of the natural vegetation had been converted into crop fields. At present the rift valley region as a whole is a zone of intensive farming activities.

Increasing and progressive settlement has replaced the natural vegetation with small to medium scale farming. The study area is no different from this wave of influence as a considerable part of it lies in the Rift Valley floor and the escarpment where many development processes are on the way. Figure 9 shows land clearings for farming.

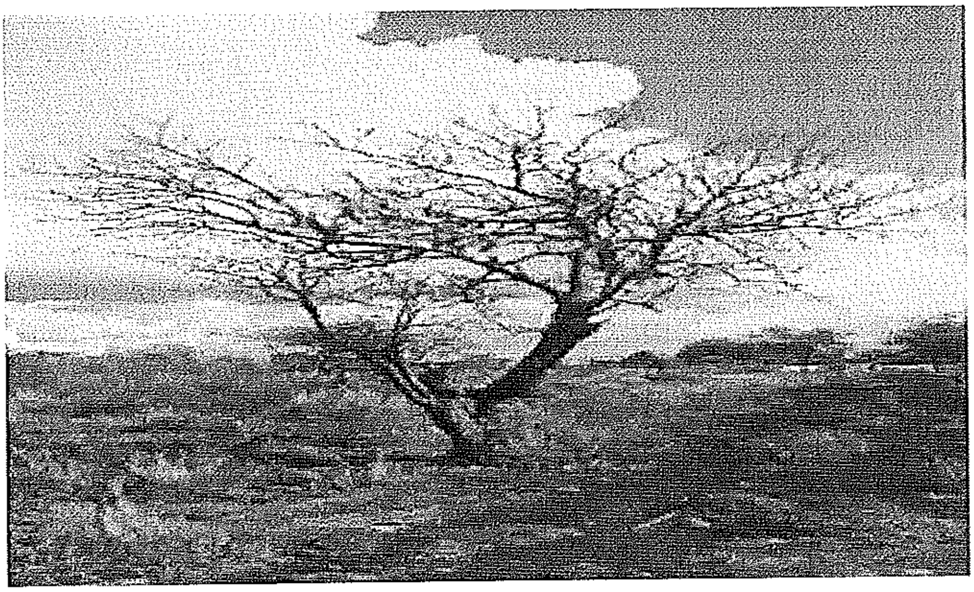

Figure 8. Land cleared for farming

The land use classification of the adjacent woreda of the study area is shown in Table 5.

Table 5. Land use classification of Humbo Woreda

Land use	Hectares	% Cover
Cultivated land	28435	32.81
Grazing land	8585	9.91
Bush and Shrubland	21467	24.8
Fallow land	10100	11.66
Non-Cultivable land	12000	13.85
Forest	910	1.05
Land for other uses	5149	5.94

Source: Humbo Wored Agricultural Office, 2002

Table 6. Relative distribution of topographic land form of Humbo Woreda in percentage cover

Land form	% Cover
Rugged	33
Mountanous	8
Flat plain	59

Source: Humbo Woreda Agricultural Office, 2002

Table 7. Climatic Zones of Humbo Woreda

Land type	Hectares	% Cover
Low land	60652	70
High land	25994	30

Source: Humbo Woreda Agricultural Office, 2002

3.5 Data Collection

3.5.1 Vegetation data

In order to obtain an impression of the site conditions and to identify sampling sites, one reconnaissance and two data collection trips were made to the study area between October 2003 and June 2004. Eight sampling sites were selected. These are Daleta, Hamasa Riverine, Tuba Abaya, Gengere Ollaa, Gengere Gibbuwa Abaya, Genger Oso Ollaa, Shinkiko Wanke Deriya and Garba Sites.

3.5.2 Vegetation sampling

Before arranging out the actual sampling, a reconnaissance was made across the entire vegetation in order to obtain an impression about the internal variation in site condition and physiognomy of the vegetation. Then sample plots were selected and vegetation data was collected from 55 plots. The Data collection was conducted between November 17, 2003 to December 18, 2003 (first round) and June 28, 2004 to July 14, 2004 (second round).

During sampling, visually checked homogeneous, representative stands were selected and delimited for sampling. At each sampling area, plots of 400 m^2 (20 m x 20 m) were measured. Inside each quadrat, nested plots of 20 m x 20 m for trees, 5 m x 5 m for shrubs and 2 m x 2 m for grasses and other herbs were established. All plant species in the quadrats were recorded and voucher specimens were pressed in the field for subsequent identification at the National Herbarium (ETH), Addis Ababa University.

Percentage cover values of trees, shrubs, herbs and grasses were estimated in the field and latter converted to cover/abundance values of Braun-Blanquet scales as modified by van der Maarel (1979) as follows.

1 = rare, generally one individual
2 = occasional, with less than 5% cover
3 = abundant, with less than 5% cover
4 = very abundant, with less than 5% cover
5 = 5 – 12 % cover
6 = 12.5 – 25 % cover
7 = 25.5 – 50 % cover
8 = 50.5 – 75 % cover
9 = above 75 % cover

The specimens collected were identified by comparing them with the specimens already identified at the National Herbarium in Addis Ababa University and using keys in the published volumes of Flora of Ethiopia and Eritrea were also used for identification.

3.5.3 Environmental data

The following environmental data on topographic parameters were gathered for each plot. Altitude, slope, aspect and position for each plot were determined respectively with an Altimeter, Suunto Clinometer, Suunto Compass and GPS-48.

Soil samples were collected from each plot at 0-20 cm depths. Soil samples were collected from five sites in each plot, four at the corners and one at the middle of the plot. Composite soil samples weighing about 1.5 kg were brought to the soil laboratory of the Department of Biology, Addis Ababa University for further analysis.

Soil samples were analyzed at the soil laboratory of the Biology Department of Addis Ababa University following Jackson (1973) and Juo (1978). The samples were air dried, sieved with a mesh size of 0.5 mm and 2 mm. Then the samples were analyzed for texture, pH, total nitrogen and electrical conductivity.

Texture was determined using Bouycous Hydrometer method; pH was measured using a pH meter at 1:2.5 distilled water to soil suspension while total nitrogen was determined by using Kjeldahl method. Electrical conductivity was measured by using conductivity meter.

Fifty grams of 2 mm sieved dried samples was added to 50 ml of 5% sodium hexametaphosphate along with 100 ml distilled water. The suspension was stirred with a glass rod and then allowed to stand for 30 minutes. The soil suspension was stirred using a multi-mix machine for 15 minutes, and then transferred into a one liter glass cylinder. The suspension was diluted with distilled water upto a one liter mark. The soil suspension was mixed by covering the mouth of the cylinder by hand and inverting it several times. Hydrometer and temperature readings were taken at 40 seconds and the soil suspension was allowed to settle for 2 hours. After 2 hours the readings of Hydrometer and temperature were taken for the second time. Then the different soil fractions were calculated as follows:

1. % SAND = 100 – [H_1 + 0.2 (T_1 - 68) - 2] x 2
2. % CLAY = [H_2 + 0.2 (T_2 - 68) –2] x 2
3. % SILT = 100 – (% SAND - % CLAY)

Where H_1 = the first hydrometer reading after 40 seconds.

T_1 = the temperature reading after 40 seconds.

H_2 = the hydrometer reading after 3 hours.

T_2 = the temperature reading after 3 hours.

Soil pH was determined following Juo (1978). A 1: 2.5 soil suspension in water was made by dissolving 10g of soil that has passed through 2 mm sieve with 25 ml of distilled water. The suspension was stirred with a glass rod and allowed to settle for 30 minutes. The pH was measured using pH meter.

Nitrogen was determined using the macro Kjeldahl method. The analysis of soil nitrogen requires a complete break down of the organic nitrogen (digestion), followed by distillation and titration. In the process of digestion organic nitrogen would be converted into ammonium nitrogen. Nitrogen was estimated then from the amount of ammonia liberated by distillation of the digestion with alkali.

The procedure started by taking one gram of air-dried soil that had passed through 0.5 mm sieve. It was placed in a dry 500 ml Kjeldahl flask, mixed with 7 g of potasium sulfate and 0.8 g of copper sulfate to catalyze the reaction and 12 ml of concentrated sulfuric acid was added to it. The digestion flasks were then put to the digestion system which was preheated (420°C). Samples were allowed to be digested for about one hour until all the samples were clear of green colour. After the racks of the tubes were cooled for 15 minutes, 75 ml of distilled water was added into the tube. In a conical flask 25 ml of receiver solution was added and the flask was placed into the distillation unit. In the distillation unit 50 ml of 40% sodium hydroxide was despensed and distillation allowed to go for about 4 minutes until the receiver solution in the distillate flask became green in colour indicating the presence of alkali ammonia. The distillate was then titrated with standardized 0.1N HCl until the blue gray end point was reached.

The whole reaction can be summarized as follows,

Digestion: Organic Nitrogen + $H_2SO_4 \xrightarrow[CuSO_4]{K_2SO_4} (NH_4)_2SO_4 + H_2O$

Distillation: $2(NH_4)_2SO_4 + 4NaOH \longrightarrow Na_2SO_4 + 4NH_3 + 4H_2O$

$NH_3 + H_3BO_3 \longrightarrow NH_4H_2BO_3$

Titration: $NH_4H_2BO_3 + HCl \longrightarrow NH_4Cl + H_3BO_3$

The percentage of total nitrogen was then calculated as follows.

$$\% N = \frac{(T-B) x N x 14.007}{Weight\ of\ sample(g)} x 100$$

Where

T = titration volume for sample

B = titration volume for blank

N = normality of acid.

To measure soil electrical conductivity a soil water suspension in a ratio 1: 2.5 was prepared. In this case soil water suspension was made by dissolving 10 gm of soil by 25 ml of distilled water and stirred for 30 minutes with automatic stirrer. Then electrical conductivity was measured using conductivity meter.

3.5.4 Data analysis

Multivariate data analysis methods were used to analyse the floristic composition of the vegetation. Plots were grouped into clusters with the aid of the program TWINSPAN (Hill, 1979). TWINSPAN is a polythetic method of vegetation classification. It classifies both samples and species. The resulting groups are recognized as community types. The community types identified were further characterized by means of environmental factors, which appeared to be correlated to the floristic composition of the type.

The mean values of environmental variables for each community were computed and one-way analysis of variace (ANOVA) was used to determine if there is a significant variation among environmental factors and the communities. The program SPSS 10 for window version was employed to carry out the ANOVA. Statistical measurement regarding species richness and diversity was carried out by Shannon-Wiener (1949) diversity index. The Shannon diversity index is calculated from the formula:

$$H^1 = -\sum_{i=1}^{s} P_1 l_n P_1$$

Where H^1 = diversity

S = the number of species

P_1 = the proportion of individuals or the abundance of the i^{th} Species expressed as a proportion of total cover

l_n = log $base_n$

Species evenness measures the equity of species in a given sample area. Equitability (evenness) is calculated by the following formula:

$E_H = H/H_{max} = H/l_n S$

Where E_H = the equitability

H = diversity index

l_n = log $base_n$

S = the number of species

Jaccard's Coefficient of similarity was calculated to see the species composition turnover. Jaccard's Coefficient of similarity is computed to see whether communities and species composition grades gradually or in discontinuity. Sörensen's coefficient was calculated to analyse the species similarities between my study areas with other natural vegetation types in different parts of the country.

4. RESULTS AND DISCUSSION

4.1 Description of Floristic Composition

A total of 315 species of plants representing 198 genera and 59 families were recorded from the study area (Appendix 1). Of these, Poaceae had 39 (12.38%) species, Fabaceae 38 (12.06) species, Asteraceae 22 (6.98%) species, Euphorbiaceae 15 (4.76%) species, Malvaceae 14 (4.44%) species, Acanthaceae 13 (4.13%) species, Tiliaceae 12 (3.81%) species, Cyperaceae 11 (3.49%) species, Amaranthaceae 10 (3.17%) species, Lamiaceae 9 (2.86%) species, Rubiaceae and Vitaceae had each 7 (2.22%) species, Celastraceae, Cappardiaceae and Asclepiadaceae had each 6 (1.90%) species, Sapindaceae, Anacardiaceae, Moraceae, Solanaceae and Burseraceae had each 5 (1.59%) species, Polygonaceae, Asparagaceae, Commelinaceae, Cucurbitaceae and Oleaceae had each 4 (1.27%) species, Boraginaceae, Chenopodiaceae, Combretaceae, Crassulaceae, Dracaenaceae, and Rhaminaceae had each 3 (0.95%) species, Apiaceae, Flacourtiaceae, Annonaceae, Apocynaceae, Balanitaceae, Ebenaceae, Loranthaceae, Olacaceae, and Rutaceae had each 2 (0.63%) species, and the last 19 families (See Appendix 2) had each 1 (0.32%) species and the percentage distribution of species in each family is presented in Appendix 2.

From the total species encountered in the study area, 145 (45.63%) species were herbs, 76 (24.06%) species were shrubs, 38 (12.19%) species were trees, 36 (11.25%) species were trees/shrubs, 18 (5.63%) species were climbers and 2 (0.63%) species were ferns and epiphytes each. The habits of the species recorded from the study area are presented in Figure 10. The vernacular names of 145 species were recorded in the study area for the first time (Appendix 1).

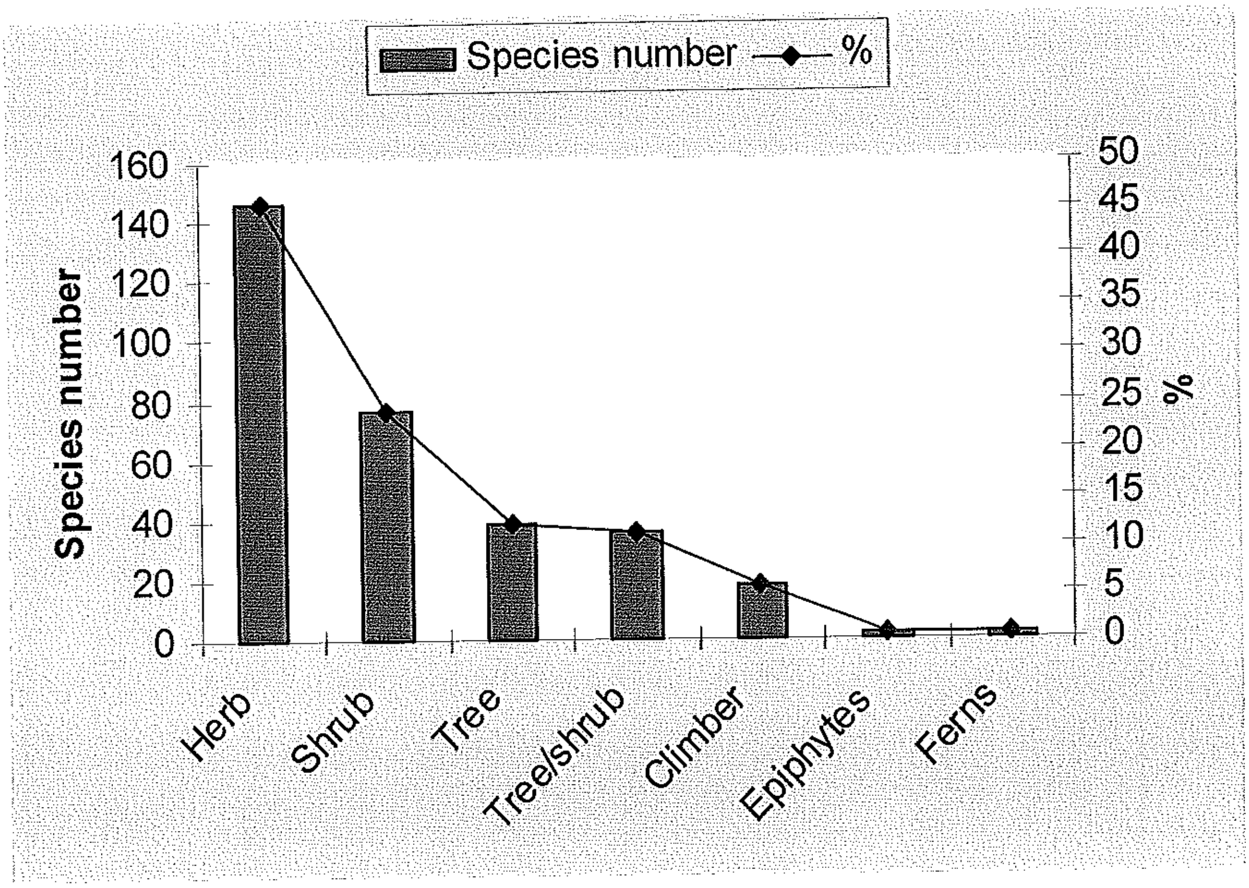

Figure 9. Habit, species number and percentage of each habit is summarized in the above figure

Species such as *Acacia brevispica, Acacia tortilis, Acalypha fruticosa, Baphia abyssinica, Cissus quadragularis, Combretum molle, Croton zambesicus, Dichrostachys cinerea, Diospyros abyssinica, Euphorbia tirucalli, Grewia bicolor, Grewia velutina, Harrisonia abyssinica, Lecaniodiscus fraxinifolius, Maerua triphylla, Pappea capensis, Rhus natalensis, Sansevieria abyssinica, Sansevieria ehrenbergii, Tamarindus indica, Teclea nobilis, Terminalia brownii, Ximenia americana,* and *Ziziphus mucronata* were widely distributed species with high frequency (Appendix 7). Each of these species occurred in 15 or more quadrats. Species recorded for the vegetation data and the quadrats in which they occur are presented in Appendix 3.

Based on the TWINSPAN output and ecological evaluations in the field, six ecologically meaningful community types (clusters) designated as 1, 2, 3, 4, 5, and 6 were identified.

The plant communities were named by the dominant and/or characteristic species, which occur in each group, using the relative magnitude of mean cover/abundance (see Table 8). Table 8 shows the mean cover abundance of major species in the community type. The species names used for the naming of the community type was based on the values in Table 8. The bold values of Table 8 are the values with which naming was done. As a result, the six community types were named after two or three of the dominant and/or characteristic species and the communities are described below.

4.2. Communities

Community 1. *Canthium setiflorum – Acacia hockii – Pappea capensis type.* This community is found at an altitudnal range of 1184 – 1309 m a.s.l. *Pappea capensis, Acacia hockii,* and *Combretum molle* are dominant tree species. The shrub layers are *Rhus natalensis, Ximenia americana, Acacia brevispica and Grewia bicolor*. Less abundant but still dominant tree species are *Commiphora africana, Terminalia brownii and Boswellia rivae. Hyparrhenia rufa, Cynodon dactylon, Laggera crispata, Heteropogon contortus, Bothriochloa insculpta,* and *Abutilon figarianum* are elements of the herb layer of the community. *Cardiospermum halicacabum, Cissus quadrangularis, C. rotundifolia, Cyphostemma adenocaule and Kleinia squarrosa* are climbers encountered in this community.

Community 2. *Commiphora africana – Acacia senegal – Balanites aegyptiaca type.* The altitudinal range of this community is from 1241 - 1410 m a.s.l. The dominant tree-shrub species are *Commiphora africana, Rhus natalensis, Acacia senegal, Harrisonia abyssinica, Balanites aegyptiaca, Ximenia americana, Ziziphus mucronata, Dichrostachys cinerea, Mystroxylon aethiopicum* and *Grewia villosa. Helichrysum schimperi, Justica flava, Leptochloa rupestris, Sehima nervosum,* *Cyperus dubius, Acalypha ciliata, Clitoria ternatea, Sansevieria ehrenbergii,* is herb surface layers.

Community 3. ***Zanthoxylum chalybeum-Commiphora habessinica- Grewia villosa type.*** This community type is found at an altitudinal range of 1233-1283 m a.s.l. *Zanthoxylon chalybeum* is characteristic shrub species of the community. *Terminalia brownii, Commiphora habessinica, Boswellia rivae, Mystroxylon aethiopicum, Grewia villosa, Croton zambesicus, Diospyros abyssinica, Grewia velutina, Tamarindus indica* are dominant tree-shrub species. *Leptochloa rupestris, Sporobolus pyramidals,* and *S. ioclados* are dominant grass species in this community.

Table 8. Synoptic Table of the Abaya – Hamassa vegetation with diagnostic species having high cover value and characteristic species. (The figures printed in bold indicate species having high cover value and characteristic species).

Community type	1	2	3	4	5	6
Cluster size	11	17	5	11	6	5
Canthium setiflorum	**1.8**	0.0	0.0	0.0	0.0	0.0
Acacia hockii	**1.3**	0.0	0.2	0.0	0.0	0.3
Pappea capensis	**1.3**	0.2	0.3	0.0	0.0	0.0
Acacia brevispica	**1.4**	0.9	0.6	2.0	1.9	0.7
Grewia bicolor	**1.3**	1.0	0.6	1.5	0.0	0.4
Combretum molle	**1.9**	0.2	1.3	1.7	0.2	0.6
Commiphora africana	0.5	**4.1**	0.2	0.0	0.1	0.0
Rhus natalensis	1.3	**4.0**	1.6	0.5	0.1	0.0
Acacia Senegal	0.5	**2.6**	0.0	0.0	0.0	0.0
Harrisonia abyssinica	1.0	**2.0**	0.7	0.1	1.6	4.0
Balanites aegyptiaca	0.2	**1.2**	0.0	0.0	0.0	0.0
Ximenia Americana	0.6	**1.1**	0.0	0.0	0.0	0.0
Ziziphus mucronata	0.3	**1.5**	0.4	0.0	0.6	1.3
Dichrostachys cinerea	0.0	**1.4**	0.4	0.7	0.1	0.0
Terminalia brownii	0.5	0.2	**3.4**	0.8	0.7	0.4
Zanthozylon chalybeum	0.3	0.0	**1.8**	0.0	0.0	0.0
Commiphora habessinica	0.0	0.2	**1.5**	0.0	0.0	0.0
Boswellia rivae	0.6	0.4	**1.9**	0.1	0.0	0.0
Mystroxylon aethiopicum	0.0	0.8	**1.3**	0.6	0.0	0.0
Sansevieria ehrenbergii	0.3	0.9	**1.3**	0.2	0.0	0.0
Grewia villosa	0.0	0.7	**1.2**	0.0	0.2	0.0
Acalypha fruticosa	1.0	1.0	0.0	**2.9**	0.7	0.3
Teclea nobilis	1.0	0.2	0.1	**2.6**	2.8	1.0
Baphia abyssinica	0.0	0.0	0.2	**2.4**	4.3	3.0
Croton zambesicus	0.2	0.0	1.3	**1.9**	1.6	4.6
Euphorbia tirucalli	0.0	0.0	0.3	**1.8**	0.8	2.6
Acacia nilotica	0.2	0.6	0.0	**1.7**	0.1	0.0
Indigofera schimperi	0.1	0.1	0.0	**1.5**	0.2	0.0
Lecaniodiscus fraxinifolius	0.0	0.0	0.6	**1.2**	2.4	0.2
Maerua triphylla	0.8	0.2	0.5	0.5	**3.6**	0.0
Diospyros abyssinica	0.0	0.0	0.7	0.7	**3.8**	3.2
Olea capensis	0.0	0.0	0.0	0.5	**3.0**	1.3
Grewia velutina	0.8	0.7	0.9	0.4	**2.7**	0.4
Tamarindus indica	0.0	0.0	1.0	0.0	**2.1**	0.0
Dodonaea angustifolia	0.0	0.4	0.0	0.1	**1.9**	0.2
Allophylus rubifolius	0.0	0.1	0.1	0.0	**1.3**	0.0
Euclea divinorum	0.0	0.0	0.0	0.2	**1.3**	0.0
Carissa spinarum	0.0	0.0	0.0	0.0	**1.3**	0.1
Acokanthera schimperi	0.0	0.0	0.1	0.1	**1.3**	0.3
Syzygium guineense	0.0	0.0	0.0	0.0	0.8	**1.8**
Olea europaea	0.0	0.0	0.0	0.0	0.9	**1.6**
Acalypha racemosa	0.0	0.0	0.0	0.0	0.3	**1.4**
Salacia congolensis	0.0	0.0	0.0	0.0	0.0	**1.2**

Community 4. *Acalypha fruticosa – Teclea nobilis – Baphia abyssinica type.* This community exists at altitudes between 1188-1397 m a.s.l. *Acalypha fruticosa, Teclea nobilis, Baphia abyssinica, Croton zambesicus, Euphoribia tirucalli, Acacia nilotica, Indigofera schimperi, Lecaniodiscus fraxinifolius, and Acacia tortilis* are dominant tree-shrub species. Less abundunt but important species in this community are *Maerua triphylla, Diospyros abyssinica, Olea capensis subsp. macrocarpa* and *Grewia velutina.* On the other hand climber species do also contain *Abrus precatorius, Glycine wightii, Monanthotaxis parvifolia, Cissus petiolata, Cynanchum altiscandens, and Salacia congolensis* with lesser cover values. Species such as *Peristrophe panicudata, Gomphocarpus purpurascens, Momordica friesiorum,* and *Bidens pilosa* are with relatively less surface cover.

Community 5. *Maerua triphylla – Diospyros abyssinica – Olea capensis type.* Altitudinal distribution of this community type is found between 1213 – 1280 m a.s.l. Dominant tree species of this community are *Baphia abyssinica, Lecaniodiscus fraxinifolius, Diospyios abyssinica and Olea capensis. Maerua triphylla, Grewia velutina, Dodonaea angustifolia, Euclea divinorum, Carissa spinarum,* and *Acokanthera schimperi* are tree- shrub species. *Tamarindus indica, Carissa spinarum* and *Euclea divinorum* are characteristic species of this community. Species such as *Syzygium giuneense, Olea europaea* and *Flacourtia indica* are with relatively high cover value. *Ageratum conyzoides, Cynodon dactylon, Xanthium spinosum, Triumfetta rhomboidea, Amaranthus caudatus Centella asiatica, Lactuca inermis* are herbacious surface layer species.

Community 6. *Croton zambesicus–Harrisonia abyssinica–Diospyros abyssinica type.* This community type is distributed at altitudes between 1225 and 1258 m a.s.l. *Salacia congolensis* is the characteristic shrub species of the community. Species such as *Acalypha racemosa, Syzygium guineense,* *Olea europaea, and Flacourtia indica* are tree – shrub species with high cover value. On the other hand the following species *Portulaca oleracea, Pupalia lappacea, Ruellia prostrata, Annonia senegalensis, Datura stramonium, Chenopodium schimperianum, Ficus vasta, Galinsoga parviflora, Hippocratea africana, Hygrophila schulli, Mollugo nudicauls, Oncoba spinosa, Ocimum urticifolium and Ozoroa insignis* are only recorded at this community in the entire study area. The vegetation data demonstrated in presence/absence form between communities are presented in Appendix 4.

4.3. Community and Diversity Indices

The Shannon diversity index (H) is a commonly used index to characterize species diversity in a community.

Among the six communities, the Shannon-Wiener diversity index result shows community 1 to be the richest in number of species, whereas, community 6 has the lowest number of species (Table 9). Community 1 has the highest species diversity (2.798) with the highest number of species (144) followed by 2, 4, 5, 6 and 3 with species diversity 2.381 (111), 2.360 (107), 1.775 (72), 1.606 (62) and 1.578 (71) respectively.

Generally, diversity follows the trends observed in species richness (Whittaker, 1975). It is highest in species rich and lowest in species poor community. It has been proposed that, the more numerous the species in a community, the greater the stability. In other words, high environmental stability leads to higher community stability, which inturn permits high diversity of species (Bormann and Kellert, 1991). Accordingly, community types 1, 2 and 4 are in high stable environment and therefor, have high species richness. The high species richness is probably attributed to the optimum environment that supports the woodland species or attributed to the minimum level of disturbances.

Table 9. Shannon – Wiener diversity index calculated among the 6 communities.

Community	Richness	Diversity Index (H)	Evenness (H/H_{max})
1	144	2.798	0.563
2	111	2.381	0.509
3	71	1.578	0.370
4	107	2.360	0.501
5	72	1.775	0.415
6	62	1.606	0.389

Species evenness measures the equity of species in a given sample area, or indicates lack of dominance by few species.

It shows the relative proportional abundance of a species in communities. Low evenness value indicates the dominance of few species in the sample area. The community, which is relatively lower in species richness, appears to have high evenness. Based on this, communities 3, 6 and 5 have the lower evenness values. Community 1 has the highest evenness value. In this regard, communities 1, 4 and 2 have more even representation of overall species.

Jaccard's coefficient of similarity is computed to see the similarity and dissimilarity of the six communities identified in the study area. Results of this analysis indicate that species composition similarity among the six communities is high (Table 10 & Table 11). Communities 1 & 2, 5 & 6 & 2 & 3 have relatively high similarity of species composition, whereas communities 1 & 5 and 1 & 6 have high dissimilarity of species composition. The most probable reason of species composition similarity or dissimilarity is the soil particles composition and the soil texture. The soil textural composition of communities 1, 2 and 3 is sandy clay loam and that of communities 5 and 6 is sandy loam (Table 12). The lowest species composition similarity is recorded between communities 1 and 6, that is 0.132 (13.2%). There is transition between communities 1 and 6 and 1 and 5. Comparatively small proportion of species occur in the two groups of communities in common (13.2%) and (16.8%) respectively. Generally, in all other communities the transition is gradual and species composition and diversity are similar (Table 10).

Table 10. A presence half-matrix of Jaccard's coefficients calculated among 6 communities.

Communities	1	2	3	4	5	6
1	1.000					
2	0.281	1.000				
3	0.240	0.277	1.000			
4	0.214	0.246	0.242	1.000		
5	0.168	0.213	0.221	0.210	1.000	
6	0.132	0.227	0.217	0.225	0.279	1.000

Table 11 Jaccard presence community coefficient among adjacent communities/ altitudinal ranges.

Altitudinal Ranges	Similarity coefficient	Communities
1241 – 1410/1225 – 1258	13.2%	1,6
1214 – 1410/1213 – 1280	16.8%	1, 5
1184 – 1309/1233 – 1283	27.7%	2, 3
1213 – 1280/1225 – 1258	27.9%	5, 6
1241 – 1410/1184 - 1309	28.1%	1, 2

4.4 Community-Environment Relationships

Plant growth is influenced by soil physical and chemical properties. These soil properties are important factors in determining plant growth and vegetation distribution. The test for variance of soil physical and chemical properties (Table 12) revealed that the differentiation of communities can be partly explained by the variations of soil texture and physical and chemical properties.

In the present study the environmental data collected from Abaya Hamassa (Appendix 5) were averaged in accordance with the community types identified and tested statistically for significant differences between communities as shown in Appendix 6. There is significant variation of sand particle size distribution but the variation in the percentage distribution of clay and silt particles size is not strongly varied at 0.05 level of significance. Soil particle size distribution has a considerable effect on the vegetation of the area. It affects soil aeration, water movement, root penetration and water holding capacity.

The topsoil samples collected from 55 quadrats were categorized into 3 textural classes, sandy clay loam (communities 1 and 2), sandy silt loam (communities 3 and 4) and sandy loam (communities 5 and 6). Soil texture is an important soil parameter that affects site quality. It influences the nutrient supplying ability of soil solids, soil moisture and air relations and root development (Spurr and Barnes, 1980; cited in Kumelachew Yeshitela and Tamrat Bekele, 2002).

Comparison of the community types based on the sand content of the soil shows that community type 3 is significantly different from communities 2, 4, and 5 and is significantly different from, 1, 2, 4, 5 and 6 in its clay composition. Community type 4 is significantly different from communities 1, 2, 3, 5 and 6 in its silt composition.

Table 12. Averaged values of environmental variables (± indicates SD).

Comm-unities	Altitude (m)	Slope (o)	PH	EC (mmhos/cm)	TN	% Sand	% Clay	% Silt	Texture
1	1242.42 ±30.89	6.65 ±8.02	7.12 ±0.48	3.28 ±1.09	0.54 ±0.48	50.00 ±17.47	26.41 ±14.23	23.59 ±7.47	Sandy clay loam
2	1288.18 ±49.75	12.09 ±10.60	6.67 ±0.53	3.62 ±0.97	0.84 ±0.89	48.45 ±13.43	27.09 ±9.60	24.45 ±7.24	Sandy clay loam
3	1257.80 ±22.02	15.20 ±11.95	6.58 ±0.32	3.60 ±0.24	0.36 ±0.24	52.20 ±9.91	21.00 ±5.66	26.80 ±6.53	Sandy silt loam
4	1244.78 ±37.33	9.89 ±8.49	6.83 ±0.59	3.13 ±1.03	1.02 ±0.82	48.67 ±10.22	24.11 ±8.05	27.22 ±5.83	Sandy silt loam
5	1241.33 ±26.93	12.17 ±5.12	6.75 ±0.23	2.83 ±0.44	1.72 ±1.14	48.50 ±14.68	25.33 ±12.16	25.17 ±5.42	Sandy loam
6	1239.60 ±12.93	9.80 ±9.96	6.70 ±0.20	3.30 ±0.72	0.76 ±0.74	50.60 ±19.37	25.00 ±11.79	24.40 ±9.34	Sandy loam

Soil particles distribution among the communities is more or less similar. The proportion of sand in community 3 is the highest (52.2%) and the lowest (48.5%) in community 5. The proportion of clay is high (27.09%) in community 2 and it is low (21%) in community 3. The proportion of silt is high (27.2%) in community 4 and it is low (23.6%) in community 1. In general, the variation of soil particles distribution among communities is low. Regarding this, the variation of sand among communities is the lowest when compared with clay and silt variation (Table 12).

Soil pH affects the growth of plants and the distribution of vegetation types by its effect on the availability of mineral nutrients and decomposition of organic matter. The averaged pH values of the six communities range between 6.58 and 7.12. Soils of communities 2, 3, 4, 5 and 6 have neutral pH values whereas community 1 is slightly basic. The neutrality and slightly basic character of the soil is due to low breakdown of organic matter and low leaching of the soil attributable to the very low annual rainfall. There is no significant difference in soil pH except the slight variations obtained among the communities (Table 12).

The total nitrogen content of the soils was significantly varied in 6 communities. Soils of community 5 have higher total nitrogen content but community 3 has lower total nitrogen content. The mean values of total nitrogen in decreasing order of magnitude include communities 5, 4, 2, 6, 1 and 3. In the total nitrogen content of the soil community type 5 was significantly different from community types 3, 1, 6, 2 and 4 (Table 12).

The total nitrogen content of the soil is determined by the amount of organic matter. It is higher in those community types with higher organic matter content and lowers in those having lower organic matter content (Kumelachew Yeshitela and Tamrat Bekele, 2002). Climatic conditions specially temperature and rainfall, exert a dominant influence on the amounts of nitrogen and organic matter found in the soils. In general, the decomposition of organic matter is accelerated in warm climates. Dry soils are generally, low in the organic matter hence the total nitrogen content of the study area is low, since the area is an arid or a semi-arid region.

The electrical conductivity of the soil solution is mainly determined by soluble salts of carbonates, bicarbonates, sulphates, chlorides and nitrates (Chopra and Kanwar, 1982). Electrical canductivity in communities 2 and 3 is the highest (3.60 and 3.62 mmhos/cm) respectiviley. It is lowest in community 5 that is 2.83 mmhos/cm.

Vegetation reacts variously to exposure; light-loving communities (Heliophytes) reach their highest limits on southern exposure, while shade plants, shade loving communities reach their highest limits on north, northeast and northwest exposures. Light absorption between south and north slopes in the mountain is very considerable, much greater than in the plains. The total light in a south exposure reaches 1.6 to 2.3 times higher values than in a north exposure. The effect of slope aspect as a control of radiation may not appear to be pronounced due to the low variation of altitudinal gradients among communities. Therefore, it has no significance in determining the distribution of the vegetation.

The slope of the soil surface affects vegetation directly as well as indirectly. The indirect effect is due to the influence upon the water supply of the soil and the shifting of the angle of incidence of the sun's rays, modifying the intensity of insulation. The effect of slope is seen in its influence on the run-off and drainage and consequently upon the nutrient, depth and water content of the soil. In the present study slope has shown a significant difference in the distribution of the communities. Community type 1 has gentle slope, has high species diversity. This could partly be due to high retention of water and moderate composition of soil particles comparatively. Community type 3 has steep slope, and fairly high percentage surface stone cover, with low species diversity (Table 9). The reason for low species diversity could be the less retention of water in the soil, due to the steep slope.

Community types 2 and 5 have the same mean values of slope. But both communities have different species diversity. The diversity index calculated for the 6 communities has shown that the species diversity of community type 2 was 2.381 and the species diversity of community type 5 was 1.775.

The difference in species diversity in community type 2 and in community type 5 may occurred because of different amounts of total nitrogen content in the soils of two communities. The mean values of total nitrogen content of community type 2 were 0.84 and that of community type 5 was 1.72. High species diversity in community type 2 could partly be due to the low available total nitrogen content in the soil. This agrees with the generally held belief that highly nutrient rich soils would tend to support low species diversity (Huston, 1994). This is the reason that community type 2 supports high species diversity with low nutrient content in the soil, while community type 5 supports low species diversity with high nutrient content in the soil. Since both communities have the same averaged values of slope (Table 12).

Altitude is an important environmental factor that affects atmospheric pressure, moisture, and temperature which have a strong influence on the growth and development of plants and the distribution of vegetation. The mean altitudinal variation between 6 communities identified, is significant at $P < 0.05$ level of significance (Appendix 6). The mean values of altitude in communities range between 1239.60 to 1288.18 m a.s.l.

In order to examine the significant differences and/or similarities between the community types identified, Pearson's product moment correlation coefficient comparison test was employed for the measured environmental parameters. There is significant correlation between % sand with TN. All the other environmental parameters are correlated insignificantly at $P < 0.05$ level of significance. Altitude is negatively correlated with % sand and % clay. Except these correlations, all the other environmental variables are positively correlated (Table 13).

With increasing altitude, the steepness of the surface increases and this results in the loss of soil particles. This may be the reason that altitude is negatively correlated with % sand and % clay.

Table 13. Pearson's Product-moment Correlation Coefficient for correlations (bold values are significant at $\alpha = 0.05$). ns = not significant; s = significant.

	Altitude	Slope	pH	EC	TN	Sand	Clay	Silt
Altitude	1							
Slope	0.235 ns 0.653	1						
pH	0.253 ns 0.628	0.786 ns 0.064	1					
EC	0.049 ns 0.926	0.314 ns 0.544	0.632 ns 0.178	1				
TN	0.017 ns 0.975	0.038 ns 0.943	0.253 ns 0.629	0.753 ns 0.084	1			
Sand	-0.273 ns 0.600	0.276 ns 0.597	0.425 ns 0.400	0.510 ns 0.302	**0.848** s 0.033	1		
Clay	-0.039 ns 0.942	0.641 ns 0.171	0.471 ns 0.346	0.235 ns 0.654	0.446 ns 0.375	0.738 ns 0.094	1	
Silt	0.291 ns 0.576	0.654 ns 0.159	0.375 ns 0.464	0.084 ns 0.875	0.029 ns 0.957	0.231 ns 0.659	0.805 ns 0.053	1

The vegetation in the rift valley and escarpments were generally characterized by wooded grassland with species of *Balanites, Combretum, Terminalia, Dodonaea, Olea, Euclea* and various species of *Acacia. Acacia brevispica, Rhus natalensis, Ximenia americana, Acalypha fruticosa, Ziziphus mucronata, Grewia* spp, *Croton zambesicus* species are very common in the study area. The lake margin and swamps of the study area are covered by *Cyperus spp, Euphorbia kibwezensis, Ficus spp, Olea capensis, Sesbania goetzei, Sorghum arundinaceum, Sphaeranthus Steetzii*, and *Sida monoica* of the alkaline soils.

The cliffs of Hamassa River are covered by riverine vegetation. The dominant species are *Baphia abyssinica, Diospyros abyssinica, Euphorbia tirucalli, Ficus exasperata, Carissa spinarum, Boswellia rivae, Croton zambesicus* and *Flacourtia indica.*

The present study indicates that there is a great increase in human (Table 3) and livestock population (Table 4). Overgrazing (Figure 8) and settlement encroachments (Figure 9) are considered primary factors that affect natural vegetation of the area directly or indirectly.

Wood collection for fuel and construction, tree cutting for charcoal making and wild honey collection are some of the activities that influence the natural vegetation of the study area. Many individuals collect wild honey from nature or man made beehives. Beehives on branches of many big trees were observed in the study area. The people remove the bark of big trees to prevent honey badger climbing up, to eat honey. As a result, several big trees are found dead. At the same time, the frequent use of fire causes great vegetation destruction. There is also deliberate setting of fire to induce fresh grass and removal of ticks.

Figure 10. Big trees cut for commercial loggings and construction

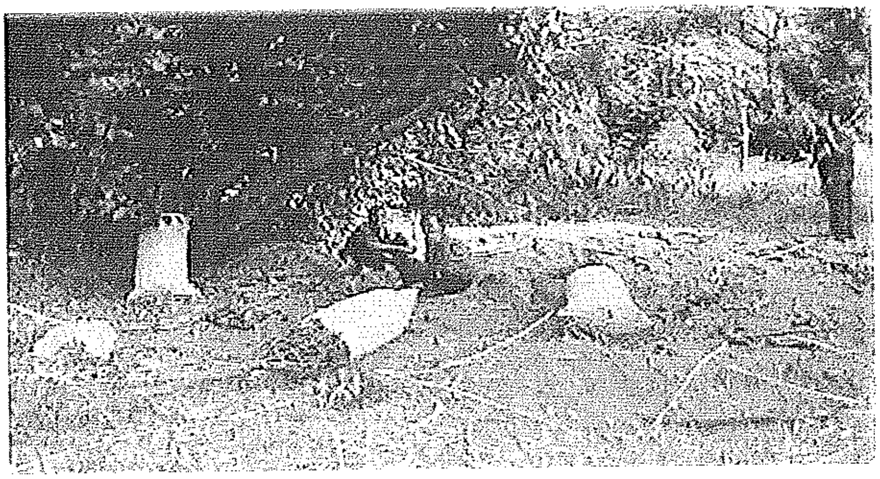

Figure 11. Illegal charcoal production

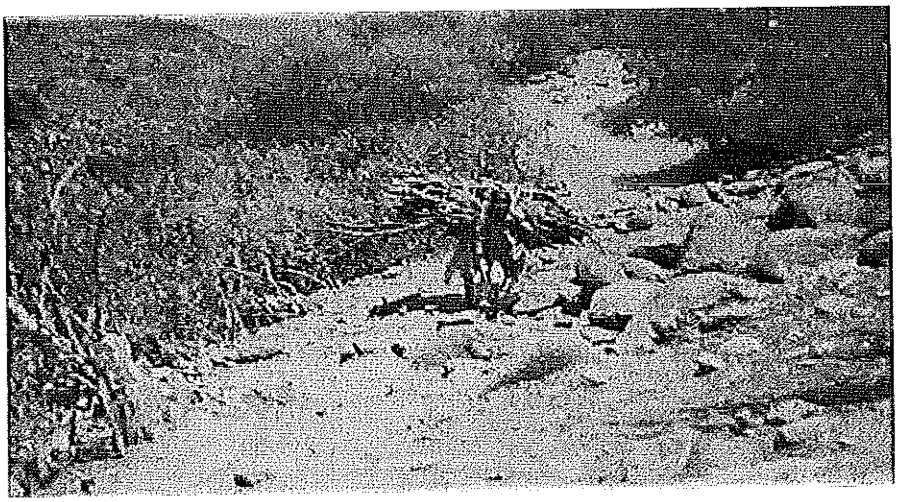

Figure 12. Collection of firewood for sale. The woman carrying firewood to Wajfo market for sale.

Discussion with local people, and the vegetation damage assessment during fieldwork have revealed that six main factors degrade the vegetation of the study area. These are recent bush encroachment, forest fire, trampling, and livestock fence construction, collecting firewood and cutting trees for charcoal making.

4.5. Similarity between vegetation types

The vegetation of Abaya Hamassa woodland is compared with other vegetation types in Ethiopia. The vegetations included in comparison are vegetation of Key Afer-Shala Luqa and Southwest of Lake Chamo (Teshome Soromessa, 1997), Vegetation of Lake Abaya to Chencha Highlands (Desalegn Wana, 2002), Rangeland Vegetions of Alagae and Neteli (Ali Seid, 2004), Vegetation along the Eastern Escarpment of Wello (Getachew Taddese, 2005), Vegetation of dryland parts of North Shoa (Hussien Adal, 2004), vegetation of the Savanna grassland and woodland in Nechisar National Park (Tamrat Andargie, 2001) and Vegetation of semi-wetland of Cheffa area South Wello (Bayafers Tamene, 2000).

Key Afer-Shala Luqua Vegetation is located about 709 km Southwest of Addis Ababa and 200 km South of Arbaminch between longitudes 37° 20' and 37° 32' E and latitudes 5° 41' and 5° 56' N. Key Afer-Shala Luqua lies between 600-1900 m a.s.l. in altitude. Southwest of Lake Chamo is found between longitudes 36° 34' and 36° 56' E and latitudes 5° 15' and 5° 40' N which is about 530 km from Addis Ababa. Altitudinally it ranges between 1100 m a.s.l. around Lake Chamo and 1900 m a.s.l. around Zeyise. The vegetation of Lake Abaya to Chencha highlands is located between latitudes 6° 05' and 6° 12' N and longitudes 37° 33' and 37° 39' E. Altitudinally it ranges between 1177 m a.s.l. around Lake Abaya and 2718 m a.s.l. in Chencha highlands. Rangeland Vegetations of Alagae and Neteli is located within the Ziway-Shalla drainage basin in latitude 7° 00' and 7° 30' N and longitudes 38° 00' and 38° 30' E. The altitude of the area ranges from 1540 m a.s.l. to 2075 m a.s.l. The vegetation along the Eastern escarpment of Wello is situated latitudes 11° 00'-11° 30' N and longitudes 39° 30'-40° 00' E and at an altitudinal range of 1660-1900 m a.s.l.

Dryland vegetation of North Shoa is situated between latitudes 8° 38' and 10° 42' N and longitudes 38° 40' and 40° 03' E. The elevation of the area ranges between 1050-1290 m a.s.l. Nechisar National park is located near Arbaminch town, 505 km South of Addis Ababa. It is positioned at the center of the Ethiopian Rift Valley between latitudes 5° 51' and 6° 05' N and longitudes 37° 48' E of the equater. The elevation ranges from 1110 to 1650 m a.s.l.

Cheffa vegetation situated between latitudes 10° 32' and 10° 58' N and between longitudes 39° 46' and 39° 56' E. The plain is located with an altitudinal difference of 1445 and 1520 m a.s.l.

The comparison is based on the similarities in species distribution. A similarity analysis was carried out based on the presence of species in order to evaluate the relationship between these vegetations. The similarity index used is Sörensen's Similarity Coefficient 2c /a+b where c is the number of species shared by the vegetations compared, a is the number of species in one vegetation and b is the number of species in the other vegetation. The results of the analysis are presented in Table 14.

Table 14. Floristic similarities between the vegetation in Abaya Hamassa woodland and seven natural vegetations in Ethiopia. N = number of species included in comparison, C = number of species in common, S = Sörensen's coefficient of similarity.

Vegetations	N	C	S
Vegetation of Key Afer-Shala Luqua and Southwest of Lake Chamo	216	93	0.54
Vegetation of Lake Abay to Chencha highlands	174	74	0.43
Rangeland Vegetations of Alagae and Neteli	213	65	0.33
Vegetation along the eastern escarpment of Wello.	216	97	0.58
Dryland vegetation of North Shoa.	208	67	0.34
The Savana grassland and Woodland Vegetations in Nechisar National Park.	199	83	0.48
Vegetation of semi-wetland of Cheffa area South Wello.	206	87	0.50

The vegetation in Abaya Hamassa is floristically related more to the vegetation of Key Afer-Shala Luqua and Southwest of Lake Chamo, Vegetation along the Eastern Escarpment of Wello and vegetation of semi-wetland of Cheffa area South Wello than to the Rangeland vegetations of Alagae and Neteli and Dryland vegetation of North Shoa. The species composition of vegetation of Nechisar National Park and Vegetation of Lake Abaya to Chencha Highlands are relatively similar to vegetation of Abaya Hamassa.

Species lists from these sites include some of the important species in my study area. Some species in common with the present study area are: *Acacia brevispica, A. mellifera, A. nilotica, A. senegal, A. seyal, A. tortillis, Acalypha fruticosa, Achyranthes aspera, Acokanthera schimperi, Asparagus africanus, Balanites aegyptiaca, Barleria eranthemoides, Cadaba farinosa, Cissus spp., Combretum spp. Commiphora spp, Ficus spp, Grewia spp, Cyperus spp, Rhus nalalensis, Ximenia americana* and *Ziziphus spp.*

All these natural vegetations are situated in the same ecological and climatic zones in rift valley system. Therefore, the highest floristic similarity between these vegetations is due to similar ecology and climatic conditions. However, Rangland Vegetations of Alagae and Neteli and Dryland Vegetation of North Shoa show variation. This variation could partly be attributed to vegetation disturbance.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

A total of 315 species of plants representing 198 genera and 59 families were recorded. From the total species encountered in the study area 45.63% of species were herbs, 24.06% of species were shrubs, 12.19% of species were trees, 11.25% of species were trees/shrubs, 5.63% of species were climbers and the percentage proportions of ferns and epiphytes were each 0.63%. Twenty four species (Appendix 7) were widely distributed.

The analysis of data from 55 quadrats, using computer program TWINSPAN revealed that the natural vegetation of Abaya Hamassa can be categorized into 6 plant communities. Accordingly, the plant community type 1 is *Commiphora africana - Acacia senegal - Balanites aegyptiaca.* The altitudinal range of this community is 1241-1410 m a.s.l. Community type 2 *is Canthium setiflorum – Acacia hockii- Pappea capensis,* which is found at an altitudinal range of 1184-1309 m a.s.l. Community type 3 is *Zanthoxylum chalybeum - Commiphora habessinica - Grewia villosa,* which is found at altitudinal range between 1233-1283 m a.s.l. Community type 4 is *Acalypha fruticosa - Acacia nilotica - Indigofera schimperi.* This community is found at altitudes between 1188-1379 m a.s.l. Community type 5 is *Tamarindus indica – Carissa spinarum - Euclea divinorum.* Altitudinal distribution of this community type is between 1213-1280 m a.s.l. And community type 6 is *Salacia congolensis - Syzygium giuneense - Acalypha fruticosa.* This community is distributed at altitudes between 1225 and 1258 m a.s.l.

The analysis of diversity from the vegetation data sampled from 55 quadrats showed that plant community type 1 is a species rich community while community type 6 is a species poor community. Evenness appears to be highest in community 1 and lowest in community 3.

Plant species in general change to meet varying conditions of soil, climate and the use made by man and his livestock. Increased pressure on land in recent years has resulted in continued degradation of the plant communities. This will further cause the removal of original floristic components, destruction of natural regeneration of species and overgrazing which will in turn cause soil erosion. Thus the study of the vegetation dynamics and human interaction is important for appropriate vegetation management and maintenance of biodiversity.

Biodiversity is valued and has been studied largerly because it is used, and could be used better to sustain the ever-increasing human population. Only through understanding the importance of biological diversity can conservation measures become a priority and diversity utilized in different ways.

The impact of human interference with natural vegetation seems to be evident from the present study. At present, most of the natural vegetation has changed into farmlands which are claimed as the major threat. Collection of firewood for sale and household consumption, cutting of live trees for construction, farm implements and other uses are common in the study area.

Crop production is pushing from all directions overtaking the position of natural vegetation. The surrounding communities strongly object the prohibition of collecting dry timber for building purposes and live trees for farm implements.

Therefore, to improve the natural diversity and structure of the plant communities, to minimize the influence of the surrounding communities and utilize the forest resources sustainably for present and future generation, effective conservation measures should be carried out through training and awareness creation of the indigenous people of the surrounding areas.

The local people claim that they have the right to utilize the natural resources in their localities. All concerned institutions at the local, regional and federal levels should participate in awareness creation and conservation programs. Private investors, NGOs and religious organizations also have important contributions to make in the conservation efforts and in improving the socio-economic status of the local people. Educating the local people to develop community based environmental conservation by integrating indigenous traditional knowledge with the modern strategy is highly needed. This may also generate income. The local people who have settled around the area should participate in the management decissions and accrue the benefit.

5.2. Recommendation

Based on the findings of this study it is suggested that the present trend of heavy exploitation of plant species in the area reduces the vegetation cover and may lead to local extinction of species. Hence a proper use and conservation practices, which promote natural regeneration based on well worked out management plans should be adopted at the earliest possible time.

Big trees such as *Acacia* spp., *Diospyros abyssinica, Commiphora spp. Combretum molle* and *Ficus species* are cut down for charcoal making, firewood, for construction and the vegetation is cleared for cultivation. In this regard alternatives for the shift in land use should be considered for maintaining the livelihood of the people. The options may include the development of eco-tourism, which could be designed to serve for both nature conservation and income generation for the surrounding population.

Effective conservation measures should be carried out through an extension work to create awareness among the local community. The aim should be to promote a situation where environmental conservation forms part of a multiple land-use system. The local people should develop their awareness on conservation, so that they would appreciate the benefits of nature conservation. It is important to integrate the useful indigenous knowledge and modern conservation systems to develop a deeper understanding of the species and their ecosystems.

Local communities should be encouraged to focus on conservation issues through the support of community initiated projects.

The study area supports different vegetation types so that the conservation of this vegetation types should be given the priority concern for the conservation of biodiversity. It is suggested that further investigation of the vegetation-environment relationships is essential by considering factors such as moisture, ambient temperature, disturbance and dispersal effects in community organization and diversity.

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Appendix 1. Vegetation Data Collected from Abaya-Hamassa study area (scientific name, family, habit and vernacular name) in Southern Ethiopia, Wolayta

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
075	*Abrus precatorius* L.	**Fabaceae**	Liana	
259	*Abutilon bidentatum* (Hochst.) A. Rich.	**Malvaceae**	Herb	
093	*A. figarianum* Webb	**Malvaceae**	Herb	Arikyaa
084	*A. graveolens* (Roxb ex Hornem.) Wight and Arn.	**Malvaceae**	herb	
008	*Acacia brevispica* Harms	**Fabaceae**	Shrub/tree	Worxxafiya
332	*A. dolichocephala* Harms	**Fabaceae**	Shrub/tree	
006	*A. drepanolobium* Harms ex Sjöstedt	**Fabaceae**	Shrub/small tree	
062	*A. hockii* Del Willd.	**Fabaceae**	Shrub/tree	Mulishaqiyaa
153	*A. mellifera* (Vahl) Both.	**Fabaceae**	Shrub/tree	
072	*A. nilotica* (L.) Willd. ex Del.	**Fabaceae**	Tree	Guuganttaa.
082	*A. senegal* (L.) Willd.	**Fabaceae**	Tree	Wangayyiya.
236	*A. seyal* Del.	**Fabaceae**	Tree	Puleesaa
033	*A. tortilis* (Forssk.) Hayne	**Fabaceae**	Tree	Xorqqaa
206	*Acalypha ciliata* Forssk.	**Euphorbiaceae**	Shrub	
210	*A. fruticosa* Forssk.	**Euphorbiaceae**	Shrub	Shatinttaa
028	*A. racemosa* Baill.	**Euphorbiaceae**	Herb/shrub	

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
098	*Achyranthes aspera* L.	**Amaranthaceae**	Herb	
022	*Acokanthera schimperi* (A. DC.) Schweinf.	**Apocynaceae**	Shrub/tree	Yiishnchaa
292	*Actinopteris semiflabellata* Pic – Serm.	**Actinopteridaceae**	Herb/Fern	
059	*Ageratum conyzoides* L.	**Asteraceae**	Herb	Zee'isaa
184	*Allophylus rubifolius* (A. Rich.) Engl.	**Sapindaceae**	Shrub	
003	*Aloe gilbertii* Sebsebe & Brandham	**Aloaceae**	Succulent shrub	Godare'uuttaa
107	*Alternanthera pungens* Kunth	**Amaranthaceae**	Herb	
270	*Amaranthus caudatus* L.	**Amaranthaceae**	Herb	Gaggabisaa
115	*A. graecizans* L.	**Amaranthaceae**	Herb	
204	*A. spinosus* L.	**Amaranthaceae**	Bushy herb	Paracumadhdhiyaa
245	*A. viridis* L.	**Amaranthaceae**	Herb	
167	*Ampelocissus bombycina* (Bak.) Planch.	**Vitaceae**	Climber	
275	*Annonia senegalensis* Pers	**Annonaceae**	Tree	
208	*Asparagus africanus* Lam.	**Asparagaceae**	Herb	
323	*A. falcatus* L.	**Asparagaceae**	Shrub	
315	*A. flagellaris* (Kunth) Baker	**Asparagaceae**	Shrub	

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
227	*A. racemosus* Willd.	Asparagaceae	Shrub	
299	*Asystasia ammophila* Ensermu	Acanthaceae	Herb	
079	*Balanites aegyptiaca* (L.) Del.	Balanitaceae	Shrub/tree	Baddanaa
021	*B. rotudifolia* (van Tieghm) Blatter	Balanitaceae	Shrub/tree	Doomayiyaa
034	*Baphia abyssinica* Brummitt	Fabaceae	Tree	Gibbuwaa
205	*Barleria eranthemoides* R. Br. ex C. B. Clarke	Acanthaceae	Spiny shrub	
324	*B. parviflora* R. Br. ex T. Anders.	Acanthaceae	Shrub	
300	*B. ventricosa* Hochst. ex Nees	Acanthaceae	Shrub	
099	*B. quadrispina* Lindau	Acanthaceae	Shrub	
132	*Bidens pilosa* L.	Asteraceae	Herb	Qarcochaa
101	*Blepharis maderaspatensis* (L.) Roth	Acanthaceae	Perennial herb	
261	*Boerhavia erecta* L.	Nyctaginaceae	Herb	
087	*Boswellia rivae* Engl.	Burseraceae	Tree	Woshilechcha
157	*Bothriochloa insculpta* (Hochst. ex A. Rich) A. Comus.	Poaceae	Herb	
218	*Brachiaria eruciformis* (J. E. Smith) Griseb	Poaceae	Annual	
104	*Bridelia micrantha* (Hochst.) Baill.	Euphorbiaceae	Shrub	

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
015	*Cadaba farinosa* Forssk.	**Capparidaceae**	Shrub	Deeshshafila
200	*Calpurnia aurea* (Ait.) Benth.	**Fabaceae**	Shrub/small tree	Maylluwa
199	*Canthium pseudosetiflorum* Bridson	**Rubiaceae**	Shrub	
010	*C. setiflorum* Hiern	**Rubiaceae**	Shrub	Shenderaa
064	*Capparis fascicularis* DC.	**Capparidaceae**	Shrub	Uguuggiyaa
316	*C. tomentosa* Lam.	**Capparidaceae**	Shrub	
089	*Cardia monoica* Roxb.	**Boragnaceae**	Tree	Eeraa
106	*Cardiospermum halicacabum* L.	**Sapindaceae**	Annual climber	
007	*Carduus leptacanthus* Fresen.	**Asteraceae**	Herb	
071	*Carissa spinarum* L.	**Apocynaceae**	Climber/shrub	Laadiyaa
170	*Centella asiatica* (L.)Urban	**Apiaceae**	Creeping herb	
267	*Chamaecrista mimosoides* (L.) Greene	**Fabaceae**	Shrub	
154	*Chenopodium ambrosiöides* L.	**Chenopodiaceae**	Herb	
027	*C. opulifolium* Schrader ex Koch and Ziz.	**Chenopodiaceae**	Herb	
213	*C. schraderianum* Schult.	**Chenopodiaceae**	Shrub	
282	*Chloris gayana* Kunth	**Poaceae**	Grass	

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
302	*Chlorophytum zavattarii* (Cufod.) Nordal	**Anthericaceae**	Herb	
009	*Cirsium vulgare* (Sav.) Ten	**Asteraceae**	Herb	
077	*Cissus petiolata* Hook. f.	**Vitaceae**	Climber/scrambler	
313	*C. quadrangularis* L.	**Vitaceae**	Succulent climber herb	
016	*C. rotundifolia* (Forssk.) Vahl	**Vitaceae**	Climber	
219	*Cleome gynandra* L.	**Capparidaceae**	Herb	Gemeeduwaa
173	*Clitoria ternatea* L.	**Fabaceae**	Annual or short lived perenial	
073	*Combretum collinum* Fresen. *ssp. Binderianum* (Kotschy) Okafor	**Combretaceae**	Tree	Qarcciituwa
076	*C. molle* R. Br. ex G. don.	**Combretaceae**	Tree	Sobbuwaa
304	*Commelina benghalensis* L.	**Commelinaceae**	Herb	
036	*C. diffusa* Burm. f.	**Commelinaceae**	Herb	Dale'ishaa
215	*C. erecta* L.	**Commelinaceae**	Herb	Dale'ishaa
217	*C. petersii* Hassk.	**Commelinaceae**	Herb	Dale'ishaa
086	*Commiphora africana* (A. Rich.) Engl.	**Burseraceae**	Tree	Anisaa
094	*C. bruceae* Chiov.	**Burseraceae**	Tree	Anisaa

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
183	*C. habessinica* (Berg) Engl.	**Burseraceae**	Tree	Anisaa
181	*C. schimperi* (Berg) Engl.	**Burseraceae**	Tree	Anisaa
243	*Corchorus olitorius* L.	**Tiliaceae**	Herb	Mulikkayiyaa
296	*Crossandra nilotica* Oliv.	**Acanthaceae**	Shrub	
130	*Crotalaria axillaris* Ait.	**Fabaceae**	Shrub	
117	*C. incana* L.	**Fabaceae**	Herb	
128	*C. laburnifolia* L.	**Fabaceae**	Shrub	
129	*C. pallida* Ait.	**Fabaceae**	Shrub	
237	*C. pycnostachya* Benth.	**Fabaceae**	Herb	
050	*C. spinosa* Hochst. ex Benth.	**Fabaceae**	Herb	
011	*Croton zambesicus* Muell. Arg.	**Euphorbiaceae**	Shrub/tree	Baallibadiya
230	*Cucumis prophetarum* L.	**Cucurbitaceae**	Herb	
309	*Cyathula cylindrica* Moq.	**Amaranthaceae**	Shrub	
310	*C. orthacantha* (Aschers.) Schinz	**Amaranthaceae**	Shrub	
253	*Cymbopogon excavatus* (Hochst.) Stapf.	**Poaceae**	Grass	
248	*Cynanchum altiscarndens* K. Schum.	**Asclepiadaceae**	Climber/herb	

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
121	*Cynodon dactylon* (L.) Pers.	**Poaceae**	Perennial	Suraa
249	*Cyperus alopecuroides* Rottb.	**Cyperaceae**		
278	*C. articulatus* L.	**Cyperaceae**	Annual herb	Bedaariyaa
143	*C. assimilis* Stewd.	**Cyperaceae**	Annual	
279	*C. distans* L. f.	**Cyperaceae**	Annual herb	
281	*C. dubius Rottb. ssp. Macrocephalus* (C.B. Clarke) Lye	**Cyperaceae**	Annual herb	
120	*C. fischerianus* A. Rich.	**Cyperaceae**	Perennial	
127	*C. haspon* L.	**Cyperaceae**	Herb	
280	*C. nutans* Vahl	**Cyperaceae**	Annual herb	Ceeccaa
151	*C. rotundus* L.	**Cyperaceae**	Herb	Xettaa
235	*Cyphostemma adenocaule* (Steud. ex A. Rich.) Descoings ex Wild & Drummond	**Vitaceae**	Climber/scrambler	
124	*Datura stramonium* L.	**Solanaceae**	Herb	Machchaara
179	*Desmodium repandum* (Vahl) DC.	**Fabaceae**	Climber	
322	*Dicrocephala chrysanthemifolia (*Bl.) DC.	**Asteraceae**	Shrub/herb	
046	*Dichrostachys cinerea* (L.) Wight & Arn.	**Fabaceae**	Shrub/small tree	Gargaruwaa

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
283	*Digitaria velutina* (Forssk.) P. Beauv.	**Poaceae**	Grass	
156	*Dinebra retroflexa* (Vahl) Panzer	**Poaceae**	Annual	
002	*Diospyros abyssinica* (Hiern) F. White	**Ebenaceae**	Tree	Gurchuwaa
092	*Dodonea angustifolia* L. f.	**Sapindaceae**	Shrub	Sankaaraa
284	*Echinochloa colona* (L.) Link	**Poaceae**	Grass	
052	*E. haploclada* (Stapf) Stapf	**Poaceae**	Perennial	
056	*E. pyramidalis* (Lam.) Hitchc. & Chase	**Poaceae**	Perennial	
012	*Ehretia cymosa* Thonn	**Boraginaceae**	Tree	
035	*Elaeodendron buchananii* (Loes.) Loes.	**Celastraceae**	Shrub/tree	
150	*Eleusine indica* (L.) Gaertn.	**Poaceae**	Annual	Axiixiyaa
256	*Endostemon tereticaulis* (Poir.) M. Ashby.	**Lamiaceae**	Shrub	
288	*Enteropogon macrostachyus* (Hochst. ex A. Rich.) Benth.	**Poaceae**	Grass	
155	*Eragrostis aspera* (Jacq.) Nees	**Poaceae**	Annual herb	
145	*E. cilianensis* (All.) Vign. ex Janchen	**Poaceae**	Annual herb	
139	*Erianthemum dregei* (Eckl. & Zeyl.) Tieghem	**Loranthaceae**	Epiphyte	Bawiyaa
307	*Eriochloa fatmensis* (Hochst. & Steud.) Clayton	**Poaceae**	Grass	

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
123	*Eriosema psoraleoides* (Lam.) G. Don	**Fabaceae**	Shrub	
234	*Erythrina abyssinica* Lam. ex DC.	**Fabaceae**	Tree	Bortuwa
164	*Euclea divinorum* Hiern	**Ebenaceae**	Shrub/small tree	Megara
330	*Euphorbia kibwezensis* Pax	**Euphorbiaceae**	Tree	Akkirsaa
163	*E. polyacantha* Boiss.	**Euphorbiaceae**	Shrub	
168	*E. schimperiana* Scheele	**Euphorbiaceae**	Sub shrubby	Tontoloshiya
161	*E. tirucalli* L.	**Euphorbiaceae**	Tree	Maaxxuwaa
085	*Ficus exasperata* Vahl	**Moraceae**	Tree	Wolaa
274	*F. ingens* (Miq.) Miq.	**Moraceae**	Tree	Wolaa
203	*F. sycomorus* L.	**Moraceae**	Tree	
180	*F. thonningii* Blume	**Moraceae**	Tree	
312	*F. vasta* Forssk.	**Moraceae**	Tree	
148	*Fimbristylis bisumbellata* (Forssk.) Bub	**Cyperaceae**	Annual	
051	*Flacourtia indica* (Burm.f.) Merr.	**Flacourtiaceae**	Shrub/tree	Haglaa
109	*Flaveria trinervia* (Spreng.) C. Mohr	**Asteraceae**	Shrub	
239	*Flueggea virosa* (Willd.) Voigt.	**Euphorbiaceae**	Shrub/small tree	

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
057	*Galinsoga parviflora* Cav.	**Asteraceae**	Herb	Biziddiya
134	*Gardenia ternifolia* Schum. & Thonn.	**Rubiaceae**	Shrub	
264	*Glycine wightii* (Wight & Arn.) Verdc. ssp wightii	**Fabaceae**	Climber herb	
232	*Gomphocarpus fruticosus* (L.) Ait.f.	**Asclepiadaceae**	Shrubby herb	
108	*G. integer* (N.E. Br.) Bullock	**Asclepiadaceae**	Herb	
110	*G. purpurascens* A. Rich.	**Asclepiadaceae**	Herb	
031	*Gomphrena celosioides* Mart.	**Amaranthaceae**	Herb	
001	*Grewia bicolor* Juss.	**Tiliaceae**	Shrub/tree	Xawayyiyaa
111	*G. erythraea* Schweinf.	**Tiliaceae**	Shrub	
112	*G. ferruginea* Hochst. Ex A. Rich.	**Tiliaceae**	Shrub	
014	*G. flavescens* Juss.	**Tiliaceae**	Liana	
023	*G. tembensis* Fresen.	**Tiliaceae**	Shrub	
140	*G. tenax* (Forssk.) Fiori	**Tiliaceae**	Shrub	
025	*G. trichocarpa* Hochst. ex A. Rich.	**Tiliaceae**	Shrub/tree	
080	*G. velutina* (Forssk.) Vahl	**Tiliaceae**	Shrub/small tree	Allagashiyaa
026	*G. villosa* Willd.	**Tiliaceae**	Shrub	Worapuuttuwaa

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
331	*Guizotia gillettii*	**Asteraceae**	Herb	
043	*G. scabra* (Vis.) Chiov.	**Asteraceae**	Herb	Adel'eciishshaa
063	*Harrisonia abyssinica* Oliv.	**Simaroubaceae**	Shrub	Kanakasilettaa
326	*Helichrysum schimperi* (Sch. Bip. ex A. Rich.) Moeser	**Asteraceae**	Herb	
138	*Heteropogon contortus* (L.) Roem. & Schult.	**Poaceae**	Perennial	Albbuwaa
226	*Hibiscus aponeurus* Sprague and Hutch.	**Malvaceae**	Herb/shrub	
209	*H. cannabinas* L.	**Malvaceae**	Herb	
220	*H. dongolensis* Del.	**Malvaceae**	Herb/shrub	
175	*H. panduriformis* Brum. f.	**Malvaceae**	Herb	
223	*H. pycnostemon* Hochr.	**Malvaceae**	Herb	
207	*Hippocratea africana* (Willd.) Loes.	**Celastraceae**	Shrub	
240	*Hoslundia opposita* Vahl	**Lamiaceae**	Shrub	
118	*Hygrophila schulli* (Hamilt.) M. R. Almeida & S. M. Almeida	**Acanthaceae**	Herb	Para'aguntaa
116	*Hyparrhenia rufa* (Nees) Stapf.	**Poaceae**	Herb	Mattosiyaa
229	*Indigofera schimperi* Jaub. & Spach	**Fabaceae**	Herb	Dandrettaa

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
149	*I. spicata* Forssk.	**Fabaceae**	Shrub	
286	*Ischaemum afrum* (J.F. Gmel.) Dandy	**Poaceae**	Grass	
257	*Jasminum floribundum* R. Br. ex Fresen.	**Oleaceae**	Liana	
146	*J. grandiflorum L. ssp floribundum L.* (R. Br. ex Fresen) P. S. Greene.	**Oleaceae**	Liana	
176	*Justicia cufodontii* (Fiori) Ensermu	**Acanthaceae**	Herb	
096	*J. flava* (Vahl) Vahl	**Acanthaceae**	Herb	
225	*J. ladanoides* Lam.	**Acanthaceae**	Herb	
192	*Kalanchoe glaucescens* Britten	**Crassulaceae**	Herb	
020	*K. lanceolata* (Forssk.) Pers.	**Crassulaceae**	Herb	
019	*K. marmorata* Bak.	**Crassulaceae**	Herb	
067	*Kleinia squarrosa* Cufod.	**Asteraceae**	Liana	
103	*Lecaniodiscus fraxinifolius* Bak.	**Sapindaceae**	Tree	Olonchuwaa
038	*Lactuca inermis* Forssk.	**Asteraceae**	Herb	
187	*Laggera crispata* (Vahl) Hepper & Wood	**Asteraceae**	Herb	Geleshshotambuwaa
039	*L. pterodonta* (DC.) Oliv.	**Asteraceae**	Herb	
277	*Leptochloa rupestris* C. E. Hubb	**Poaceae**	Grass	

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
308	*Leucas glabrata* (Vahl) Sm.	**Lamiaceae**	Shrub	
125	*Leucas martinicencis* (Jacq.) R. Br.	**Lamiaceae**	Herb	Haregaabbula
272	*Ludwigia stolonifera* (Guill. & Perr.) Raven	**Onagraceae**	Herb	
321	*Lycopersicon esculentum* (L.) Karst.	**Solanaceae**	Herb	Pugguwaa
091	*Maerua angolensis* DC.	**Capparidaceae**	Shrub/tree	Ambilettaa
005	*M. triphylla* A. Rich.	**Capparidaceae**	Shrub/tree	Tambuwaa
306	*Mariscus macropus* (Böck.) C. B. Clarke	**Cyperaceae**	Herb	
319	*Maytenus undata* (Thunb.) Blakelock	**Celastraceae**	Tree	
196	*M. arbutifolia* (A. Rich.) Wilczek	**Celastraceae**	Shrub	
029	*Meineckia phyllanthoides* Baill.	**Euphorbiaceae**	Herb	
317	*Melanthera abyssinica* (Sch. Bip. ex A. Rich.) Benth. & Hook. f.	**Asteraceae**	Herb	
269	*Mollugo nudicaulis* Lam.	**Molluginaceae**	Herb	
247	*Momordica friesiorum* (Harms) C. Jeffrey	**Cucurbitaceae**	Herb	
260	*M. pterocarpa* H. ex A. Rich.	**Cucurbitaceae**	Hlimber herb	
246	*M. sessilifolia* Cong.	**Cucurbitaceae**	Herb	
268	*Monanthotaxis parvifolia* (Oliv.) Verdc.	**Annonaceae**	Climber	

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
318	*Mystroxylon aethiopicum* (Thunb.) Loes.	**Celastraceae**	Shrub	
242	*Ochna inermis* (Forssk.) Schweinf. ex Penzing.	**Ochnaceae**	Shrub	
172	*Ocimum canum* Sims	**Lamiaceae**	Herb	Zitiituwaa
060	*O. urticifolium* Roth	**Lamiaceae**	Shrub	Gulluwaa
137	*Olea europaea* L.	**Oleaceae**	Tree	Wogaraa
030	*O. capensis* Bak.	**Oleaceae**	Shrub/tree	Haattamaaxxuwaa
273	*Oncoba spinosa Forssk.*	**Flacourtiaceae**	Shrub	
144	*Oncocalyx schimperi* (A. Rich.) M. Gilbert	**Loranthaceae**	Epiphyte	Bawiyaa
231	*Opuntia ficus-indica* (L.) Miller	**Cactaceae**	Shrub/small tree	
241	*Osyris quadripartita* Decn.	**Santalaceae**	Shrub	Malixaanuwaa
048	*Oxygonum sinuatum* (Meisn.) Dammer	**Polygonaceae**	Serb	Qum'aqum'uwaa
070	*Ozoroa insignis* Del.	**Anacardiaceae**	Shrub/tree	
212	*O. pulcherrima* (Schweinf.) R. & A. Fernandes	**Anacardiaceae**	Shrub/tree	Dachchiyaa
191	*Panicum maximum* Jacq.	**Poaceae**	Perennial	
298	*P. porphyrrhizos* Steud.	**Poaceae**	Grass	
114	*P. repens* L.	**Poaceae**	Perennial	Garbaatiyaa

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
018	*Pappea capensis* Eckl. & Zeyh.	**Sapindaceae**	Tree	Ceecilliyaa
162	*Paspalum scrobiculatum* L.	**Poaceae**	Penennial	
201	*Pavetta gardeniifolia* A. Rich.	**Rubiaceae**	Shrub	
271	*Pavonia melhanioides* Thulin	**Malvaceae**	Perennial herb	
329	*P. propinqua* Garcke	**Malvaceae**	Shrub	
291	*Pellaea calomelanos* (Sw.) Link	**Pteridaceae**	Herb/Fern	
037	*Pennisetum clandestinum* Chiov.	**Poaceae**	Annual	gorxaa
105	*P. ramosum* (Hochst.) Schweinf.	**Poaceae**	Annual	
285	*P. trachyphyllum* Pilg.	**Poaceae**	Grass	
126	*Pentarrhinum insipidum* E. Mey.	**Asclepiadaceae**	Climber	
131	*Peristrophe paniculata* (Forssk.) Brummitt	**Acanthaceae**	Herb	
289	*Perotis patens* Gand.	**Poaceae**	Grass	
122	*Persicaria senegalensis* (Meisn.) Sojak	**Polygonaceae**	Herb	
189	*Phyllanthus ovalifolius* Forssk.	**Euphorbiaceae**	Climber/shrub	
177	*P. sepialis* Muell. Arg.	**Euphorbiaceae**	Shrub	
197	*Piliostigma thonningii* (Schumach.) Milne-Redh.	**Fabaceae**	Rarely shrub/tree	Qalqalluwa

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
293	*Plectranthus cylindraceus* Hochst. Ex Benth.	**Lamiaceae**	Herb	
297	*P. longipes* Baker	**Lamiaceae**	Herb	
141	*Plumbago zeylanica* L.	**Plumbaginaceae**	Herb	
152	*Polygonum plebeium* R. Br.	**Polygonaceae**	Herb	
119	*P. senegalense* Meisn.	**Polygonaceae**	Herb	
216	*Portulaca oleracea* L.	**Portulacaceae**	Herb	
171	*Psiadia incana* Oliv. & Hiern	**Asteraceae**	Shrub	
013	*Psydrax schimperiana* (A. Rich.) Bridson	**Rubiaceae**	Shrub/tree	
186	*Pterolobium stellatum* (Forssk.) Brenan	**Fabaceae**	Liana	Gom'oryaa
102	*Pupalia lappacea* (L.) A. Juss.	**Amaranthaceae**	Herb	Maahe'xoriyaa
047	*Pycnostachys abyssinica* Fresen.	**Lamiaceae**	Shrub	
069	*Rhamphicarpa heuglinii* Hochst	**Scrophulariaceae**	Herb	
165	*Rhoicissus revoilii* Planch.	**Vitaceae**	Climber	
160	*R. tridentata* (L.f.) Wild. & Drummand	**Vitaceae**	Climber	
065	*Rhus natalensis* Krauss	**Anacardiaceae**	Shrub	Ongafriyaa
202	*R. vulgaris* Meikle	**Anacardiaceae**	Herb	

Appendix 1 Continued

Collection No	Scientifuc Name	Family	Habit	Vernacular Name Wolayta name
133	*Rhynchelytrum repens* (Willd.) C. E. Hubb.	**Poaceae**	Perennial	
263	*Rhynchosia malacophylla* (Spreng.) Boj.	**Fabaceae**	Herb	
262	*R. nyassica* Bak.	**Fabaceae**	Erect shrub	
185	*Ricinus communis* L.	**Euphorbiaceae**	Tree like herb	Qobbuwaa
244	*Ruellia prostrata* Poir.	**Acanthaceae**	Herb	
252	*Saccharum spontaneum* L.	**Poaceae**	Grass	
024	*Salacia congolensis* De Wild. & Th. Dur.	**Celastraceae**	Shrub	Phiyiyaa
194	*Salvadora persica* L.	**Salvadoraceae**	Shrub	Miiqquwaa
294	*Sansevieria abyssinica* N.E. Br.	**Dracaenaceae**	Shrub	
214	*S. ehrenbergii* Schweinfurth ex Baker	**Dracaenaceae**	Succulent shrub	Toora'alkashaa
301	*S. phillipsiae* N.E. Br.	**Dracaenaceae**	Shrub	
311	*Sarcostemma viminale* (L.) R. Br.	**Asclepiadaceae**	Climber	Turamaaxxuwaa
158	*Sclerocarya birrea* (A. Rich.) Hochst.	**Anacardiaceae**	Tree	
287	*Sehima nervosum* (Rottler) Stapf	**Poaceae**	Grass	
044	*Senna didymobotrya* (Fresen.) Irwin & Barneby	**Fabaceae**	Bushy shrub	Kuttokuwaa
228	*S. occidentalis* (L.) Link	**Fabaceae**	Herb	

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
266	*S. petersiana* (Bolle) Lack	**Fabaceae**	Shrub	Wolayta Kuttokuwaa
074	*Seratia pumila* (Poir.) Roem. & Schult.	**Poaceae**	Annual	
190	*Sesbania goetzei* Harms	**Fabaceae**	Shrub/small tree	Sookiyaa
058	*S. sesban* (L.) Merr.	**Fabaceae**	Shrub/small tree	
276	*Setaria megaphylla* (Steud.) Th. Dur. & Schinz	**Poaceae**	Annual herb/grass	
250	*S. verticillata* (L.) P. Beauv.	**Poaceae**	Grass	
233	*Sida collina* Schlechtend.	**Malvaceae**	Tree	
061	*Sida rhombifolia* L.	**Malvaceae**	Shrubby herb	Wusaawusuwaa
327	*Sida urens* L.	**Malvaceae**	Herb	
290	*Solanum glabratum* Dunal	**Solanaceae**	Shrub	
169	*S. incanum* L.	**Solanaceae**	Shrub	Buluwaa
166	*S. lanzae* F. Lebrum and Stork	**Solanaceae**	Shrub	Puxaa
135	*Sorghum arundinaceum* (Desv.) Stapf	**Poaceae**	Annual	Eceremaldduuaa
178	*Sphaeranthus steetzii* Oliv. & Hiern	**Asteraceae**	Herb	Wobaxaa
083	*S. ukambensis* Vatke & Hoffm.	**Asteraceae**	Herb	Geleshshotambuwaa
188	*Sporobolus consimilis* Fresen.	**Poaceae**	Herb	

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
254	*S. festivus* Hochst. Ex A. Rich.	**Poaceae**	Grass	
255	*S. ioclados* (Trin.) Nees	**Poaceae**	Grass	
251	*S. pyramidalis* P. Beauv.	**Poaceae**	Grass	
222	*Steganotaenia araliacea* Hochst. ex A. Rich	**Apiaceae**	Tree	Cirraaruwaa
325	*Strychnos mitis* S. Moore.	**Loganiaceae**	Tree	
045	*Stylosanthes fruticosa* (Retz.) Alston	**Fabaceae**	Herb	Kindiichuwaa
147	*Syzygium guineense* (Willd.) DC.	**Myrataceae**	Tree	Ochchaa
042	*Tagetes minuta* L.	**Asteraceae**	Herb	Wontiqammaa
017	*Tamarindus indica* L.	**Fabaceae**	Tree	Koryaa
004	*Teclea nobilis* Del.	**Rutaceae**	Shrub	Laallaa
041	*Terminalia brownii* Fresen.	**Combretaceae**	Tree	
078	*Themeda triandra* Forssk.	**Poaceae**	Perennial	
136	*Tragia plukenetii* A. Radcl-Smith	**Euphorbiaceae**	Herb	Tintalashuwaa
053	*Tribulus terrestris* L.	**Zygophyllaceae**	Herb	
221	*Tricalysia niamniamensis* Heirn	**Rubiaceae**	Shrub	Woratukkiyaa
054	*Trichodesma zeylanicum* (L.) R. Br.	**Boragnaceae**	Herb	

Appendix 1 Continued

Collection No.	Scientific Name	Family	Habit	Vernacular Name Wolayta name
314	*Triumfetta macrophylla* K. Schum.	**Tiliaceae**	Shrub	
142	*T. rhomboidea* Jacq.	**Tiliaceae**	Herb	
157	*Vangueria apiculata* K. Schum.	**Rubiaceae**	Tree	
113	*Vernonia adoensis* Sch. Bip. ex Walp.	**Asteraceae**	Shrub	Kanahamakkaa
328	*Wissadula rostrata* (Schumach. & Thonn.) Hook.f.	**Malvaceae**	Perennial herb	
055	*Xanthium spinosum* L.	**Asteraceae**	Herb	
049	*X. strumarium* L.	**Asteraceae**	Herb	Dorsaqarccochaa
066	*Ximenia americana* L.	**Olacaceae**	Shrub/tree	Asittiyaa
258	*X. caffra* Sond.	**Oleaceae**	Shrub	
193	*Zanthoxylum chalybeum* Engl.	**Rutaceae**	Shrub	Atayiifiya
068	*Zaleya pentadra* (L.) Jeffrey	**Aizoaceae**	Herb	
040	*Ziziphus mauritiana* Lam.	**Rhaminaceae**	Shrub/tree	Gaammogaadiyaa
088	*Z. mucronata* Wild.	**Rhaminaceae**	Shrub/tree	Sesilettaa
195	*Z. spina christi* (L.) Desf.	**Rhamnaceae**	Shrub	Gaammogaadiya

Appendix 2. Family, species number and percent of species number in each family of vegetation data collected from Abaya Hamassa - Wolaytta

No.	Family	Species No.	%
1	Poaceae	39	12.38
2	Fabaceae	38	12.06
3	Asteraceae	22	6.98
4	Euphorbiaceae	15	4.76
5	Malvaceae	14	4.44
6	Acanthaceae	13	4.13
7	Tiliaceae	12	3.81
8	Cyperaceae	11	3.49
9	Amaranthaceae	10	3.17
10	Lamiaceae	9	2.86
11	Rubiaceae	7	2.22
12	Vitaceae	7	2.22
13	Celastraceae	6	1.90
14	Capparidaceae	6	1.90
15	Asclepiadaceae	6	1.90
16	Sapindaceae	5	1.59
17	Anacardiaceae	5	1.59
18	Moraceae	5	1.59
19	Solanaceae	5	1.59
20	Burseraceae	5	1.59
21	Polygonaceae	4	1.27
22	Asparagaceae	4	1.27
23	Commelinaceae	4	1.27
24	Cucurbitaceae	4	1.27
25	Oleaceae	4	1.27
26	Boraginaceae	3	0.95

Appendix 2 Continued

No.	Family	Species No.	%
27	Chenopodiaceae	3	0.95
28	Combretaceae	3	0.95
29	Crassulaceae	3	0.95
30	Dracaenaceae	3	0.95
31	Rhamnaceae	3	0.95
32	Apiaceae	2	0.63
33	Flacourtiaceae	2	0.63
34	Annonaceae	2	0.63
35	Apocynaceae	2	0.63
36	Balanitaceae	2	0.63
37	Ebenaceae	2	0.63
38	Loranthaceae	2	0.63
39	Olacaceae	2	0.63
40	Rutaceae	2	0.63
41	Actinopteridaceae	1	0.32
42	Aizoaceae	1	0.32
43	Aloaceae	1	0.32
44	Anthericaceae	1	0.32
45	Cactaceae	1	0.32
46	Loganiaceae	1	0.32
47	Molluginaceae	1	0.32
48	Myrtaceae	1	0.32
49	Nyctaginaceae	1	0.32
50	Ochnaceae	1	0.32
51	Onagraceae	1	0.32
52	Plumbaginaceae	1	0.32
53	Portulacaceae	1	0.32
54	Pteridaceae	1	0.32
55	Salvadoraceae	1	0.32
56	Santalaceae	1	0.32
57	Scrophulariaceae	1	0.32
58	Simaroubaceae	1	0.32
59	Zygophyllaceae	1	0.32

Appendix 3. The species list is given here in the collection number with the quadrats (plots) in which it occurs. For the scientific names and vernacular names see appendix 1

Quadrat No.	Collection number
1	292, 315, 227, 099, 101, 199, 076, 046, 288, 264, 112, 080, 063, 277, 241, 177, 297, 065, 041
2	008, 062, 082, 236, 210, 079, 324, 010, 313, 076, 046, 234, 239, 001, 080, 063, 326, 138, 240, 096, 277, 005, 318, 241, 018, 201, 189, 202, 255, 193, 195
3	075, 008, 205, 015, 010, 071, 076, 086, 179, 046, 092, 239, 001, 063, 240, 242, 241, 078, 201, 291, 202, 262, 287, 222, 004, 066, 088
4	292, 184, 086, 092, 108, 112, 080, 277, 091, 294, 214, 135, 251, 255, 041
5	093, 062, 082, 205, 073, 092, 164, 110, 005, 241, 171, 065, 214, 301
6	008, 062, 072, 033, 012, 087, 071, 076, 086, 237, 011, 281, 164, 330, 163, 239, 001, 063, 138, 257, 277, 005, 241, 018, 047, 294, 311, 041, 049, 193
7	008, 210, 292, 003, 167, 295, 010, 076, 094, 011, 002, 164, 063, 096, 103, 005, 268, 238, 242, 018, 329, 291, 152, 016, 065, 311, 222, 017, 004, 041, 193
8	028, 022, 059, 034, 157, 269, 076, 011, 121, 322, 002, 092, 284, 051, 232, 063, 240, 103, 172, 030, 169, 251, 147, 042, 004, 314, 055
9	075, 033, 210, 184, 034, 087, 316, 089, 071, 076, 011, 046, 002, 164, 264, 001, 103, 005, 268, 030, 131, 186, 065, 004, 041, 088
10	075, 033, 210, 087, 064, 046, 002, 056, 155, 161, 001, 080, 026, 063, 116, 146, 096, 005, 029, 191, 186, 065, 228, 061, 327, 004, 328, 055, 066, 088, 040
11	008, 210, 022, 071, 076, 130, 011, 278, 280, 046, 002, 164, 161, 063, 138, 240, 229, 103, 318, 137, 030, 201, 017, 004, 142, 258, 088
12	008, 028, 299, 076, 183, 011, 046, 002, 161, 110, 001, 080, 125, 247, 018, 271, 122, 189, 293, 100, 013, 065, 222, 017, 004, 041, 193, 088
13	084, 033, 305, 323, 034, 087, 076, 304, 036, 050, 011, 322, 046, 026, 063, 103, 091, 005, 260, 271, 037, 165, 065, 185, 252, 044, 266, 017, 041, 054, 088

Appendix 3 Continued

Quadrat No.	Collection number
14	008, 022, 270, 034, 157, 170, 086, 280, 002, 123, 026, 063, 103, 318, 030, 186, 065, 185, 004, 041, 088
15	008, 062, 033, 022, 115, 087, 243, 034, 002, 161, 001, 026, 138, 116, 176, 103, 091, 005, 032, 018, 271, 119, 294, 214, 017, 041, 040, 088
16	008, 206, 210, 204, 132, 089, 076, 181, 243, 011, 002, 164, 161, 149, 225, 103, 321, 196, 061, 169, 041
17	210, 184, 275, 034, 071, 011, 002, 164, 161, 085, 051, 063, 118, 273, 070, 018, 216, 024, 147, 004, 041, 088
18	062, 059, 034, 011, 124, 002, 161, 085, 312, 051, 057, 043, 063, 207, 269, 060, 030, 024, 325
19	008, 210, 034, 077, 313, 011, 248, 046, 283, 307, 161, 001, 080, 026, 192, 103, 306, 030, 141, 294, 276, 147, 004, 041
20	028, 022, 071, 213, 076, 011, 121, 002, 092, 164, 161, 063, 318, 137, 030, 105, 186, 024, 135, 147, 004, 088
21	008, 062, 022, 184, 034, 010, 313, 011, 002, 164, 161, 001, 080, 063, 030, 102, 160, 244, 024, 294, 188, 276, 017, 041
22	008, 022, 034, 071, 011, 002, 161, 051, 103, 038, 137, 030, 241, 069, 325, 147, 004, 041
23	210, 022, 323, 034, 089, 073, 011, 002, 284, 161, 001, 080, 226, 318, 231, 018, 065, 024, 074, 147, 004, 041
24	008, 210, 034, 071, 313, 002, 203, 051, 219, 063, 103, 137, 030, 048, 162, 165, 135, 325, 147, 017, 004, 041
25	206, 028, 034, 261, 036, 011, 002, 161, 203, 246, 030, 126, 294, 058, 250, 045, 004
26	022, 261, 089, 121, 278, 279, 046, 110, 020, 019, 187, 005, 317, 065, 194, 190, 178, 083, 136, 221, 066

Appendix 3 Continued

Quadrat No.	Collection number
27	082, 079, 087, 200, 313, 086, 296, 129, 274, 001, 026, 063, 005, 298, 018, 289, 065, 252, 294, 116, 017, 004, 066, 088
28	084, 072, 082, 184, 079, 021, 087, 157, 313, 094, 046, 239, 140, 080, 063, 138, 114, 065, 214, 053, 088
29	008, 033, 210, 079, 087, 086, 046, 080, 025, 063, 018, 065, 214, 017, 004, 041, 113, 088
30	093, 006, 072, 236, 076, 313, 304, 036, 183, 001, 080, 063, 229, 103, 005, 018, 065, 041, 049, 066, 088
31	062, 184, 300, 104, 015, 010, 181, 179, 239, 080, 063, 138, 229, 096, 039, 005, 241, 212, 018, 065, 222, 017, 221, 088
32	008, 072, 082, 033, 210, 184, 079, 021, 295, 087, 010, 313, 181, 046, 139, 001, 080, 063, 223, 225, 144, 241, 298, 271, 065, 214, 311, 017, 004, 026, 066, 193
33	093, 206, 028, 184, 034, 132, 295, 087, 010, 089, 076, 023, 026, 225, 103, 137, 285, 185, 024, 276, 004
34	008, 082, 079, 021, 015, 064, 313, 183, 046, 109, 001, 111, 080, 063, 209, 005, 241, 065, 301, 214, 311, 066, 088
35	008, 062, 072, 082, 206, 087, 010, 313, 094, 086, 046, 164, 239, 001, 014, 080, 138, 220, 116, 241, 018, 065, 287, 017, 004, 078, 068, 088
36	093, 072, 033, 210, 315, 021, 015, 313, 046, 228, 148, 080, 063, 175, 229, 149, 286, 005, 317, 065, 311, 088
37	008, 072, 082, 033, 210, 184, 015, 313, 046, 132, 080, 026, 031, 067, 271, 065, 133, 214, 311, 017, 066, 088
38	008, 028, 034, 010, 071, 170, 313, 073, 011, 230, 046, 002, 161, 051, 001, 103, 272, 201, 119, 065, 294, 214, 004
39	008, 210, 079, 034, 282, 009, 313, 076, 181, 128, 011, 253, 281, 035, 001, 063, 103, 277, 005, 212, 201, 289, 294, 279, 017, 004

Appendix 3 Continued

Quadrat No.	Collection number
40	072, 082, 079, 021, 087, 076, 183, 046, 052, 256, 080, 063, 005, 212, 018, 065, 214, 233, 254, 017, 041, 066, 088
41	210, 022, 087, 010, 173, 076, 086, 046, 145, 180, 001, 080, 191, 214, 017, 004
42	008, 082, 033, 210, 028, 079, 010, 154, 313, 076, 094, 011, 046, 161, 239, 001, 277, 005, 065, 294, 214, 135, 004, 041, 066
43	008, 072, 082, 184, 079, 302, 313, 304, 181, 235, 001, 026, 063, 067, 308, 065, 214, 088
44	093, 008, 082, 033, 210, 003, 021, 015, 007, 313, 036, 086, 281, 046, 330, 001, 026, 068, 005, 214, 251, 088
45	088, 082, 033, 210, 021, 064, 106, 313, 086, 001, 080, 065, 214
46	008, 033, 210, 026, 034, 076, 304, 011, 249, 046, 150, 164, 161, 001, 080, 063, 005, 065, 294, 214, 004
47	082, 033, 208, 079, 087, 313, 076, 183, 050, 234, 001, 026, 063, 297, 065, 263, 294, 214, 004, 066, 040, 195
48	008, 033, 028, 034, 313, 076, 215, 094, 011, 151, 002, 092, 085, 051, 001, 080, 063, 103, 294, 214, 004, 088
49	082, 079, 016, 076, 181, 046, 168, 134, 232, 063, 138, 116, 229, 319, 214, 018, 065, 158, 017, 041, 066, 088
50	093; 072, 033, 210, 157, 089, 027, 076, 011, 211, 046, 156, 002, 155, 203, 331, 103, 030, 135, 004, 041, 157, 066, 258, 040
51	062, 153, 072, 033, 003, 087, 010, 073, 076, 127, 046, 092, 180, 001, 080, 063, 138, 116, 229, 103, 137, 018, 065, 017, 004, 041, 066
52	008, 210, 218, 313, 016, 217, 211, 012, 161, 001, 005, 030, 294, 004
53	259, 008, 206, 089, 098, 313, 076, 309, 120, 161, 080, 030, 294, 214, 004
54	210, 332, 062, 033, 107, 079, 132, 010, 164, 001, 080, 138, 125, 172, 197, 061, 169
55	093, 006, 236, 245, 121, 001, 063, 229, 065, 290, 169

Appendix 4. The vegetation data demonstrated in presence/absence form between communities. (1 denotes presence and 0 denotes absence of species in community).

Species	Communities					
	1	2	3	4	5	6
Abrus precatorius	1	1	0	1	0	0
Abutilon bidentatum	0	0	0	1	0	0
A. figarianum	1	1	0	1	0	0
A. graveolens	1	0	1	0	0	0
Acacia brevispica	1	1	1	1	1	1
A. dolichocephala	0	1	0	0	0	0
A. drepanolobium	1	0	0	0	0	0
A. hockii	0	1	1	0	0	1
A. mellifera	0	1	0	0	0	0
A. nilotica	1	1	0	1	0	0
A. senegal	1	1	0	0	0	0
A. seyal	1	1	0	0	0	0
A. tortilis	1	1	1	1	0	1
Acalypha ciliata	0	1	0	1	1	0
A. fruticosa	1	1	0	1	1	1
A. racemosa	0	1	1	1	1	1
Achyranthes aspera	0	0	0	1	0	0
Acokanthera schimperi	1	1	1	1	1	1
Actinopteris semiflabellata	0	1	1	0	0	0
Ageratum conyzoides	0	0	0	0	1	1
Allophylus rubifolius	1	1	1	1	0	1
Aloe gilbertii	1	1	0	0	0	0
Alternanthera pungens	0	1	0	0	0	0
Amaranthus caudatus	0	0	0	0	1	0
A. graecizans	0	0	1	0	0	0
A. spinosus	0	0	0	1	0	0

Appendix 4 Continued

Species	Communities					
	1	2	3	4	5	6
A. viridis	1	0	0	0	0	0
Ampelocissus bombycina	0	1	0	0	0	0
Annonia senegalensis	0	0	0	0	0	0
Asparagus africanus	1	0	0	0	0	0
A. falcatus	0	0	1	1	0	0
A. flagellaris	1	0	1	0	0	0
A. racemosus	0	0	1	0	0	0
Asystasia ammophila	0	0	1	0	0	0
Balanites aegyptiaca	1	1	0	1	0	0
B. rotudifolia	1	0	0	0	0	0
Baphia abyssinica	0	0	1	1	1	1
Barleria eranthemoides	0	1	0	0	0	0
B. parviflora	0	1	0	0	0	0
B. ventricosa	0	1	0	0	0	0
B. quadrispina	0	0	1	0	0	0
Bidens pilosa	0	1	0	1	0	0
Blepharis maderaspatensis	1	1	1	1	0	0
Boerhavia erecta	1	0	0	0	1	0
Boswellia rivae	1	1	1	1	0	0
Bothriochloa insculpta	1	0	0	1	1	0
Brachiaria eruciformis	0	0	0	1	0	0
Bridelia micrantha	0	1	0	0	0	0
Cadaba farinosa	1	1	0	0	0	0
Calpurnia aurea	1	0	0	0	0	0
Canthium pseudosetiflorum	0	1	0	0	0	0
C. setiflorum	1	1	1	1	0	1

Appendix 4 Continued

Species	Communities					
	1	2	3	4	5	6
Capparis fascicularis	1	0	0	0	0	0
C. tomentosa	0	0	0	1	0	0
Cordia monoica	1	0	0	1	0	0
Cardiospermum halicacabum	1	0	0	0	0	0
Carduus leptacanthus	1	0	0	0	0	0
Carissa spinarum	0	1	0	1	1	1
Centella asiatica	0	0	0	1	1	0
Chamaecrista mimosoides	0	0	0	0	1	0
Chenopodium ambrosiöides	0	1	0	0	0	0
C. opulifolium	0	0	0	1	0	0
C. schimperianum	0	0	0	0	0	1
Chloris gayana	0	0	0	1	0	1
Chlorophytum zavattarii	1	0	0	0	0	0
Cirsium vulgare	0	0	0	1	0	0
Cissus petiolata	0	0	0	1	0	0
C. quadrangularis	1	1	0	1	1	1
C. rotundifolia	1	0	0	0	0	0
Cleome gynandra	0	0	0	0	1	0
Clitoria ternatea	0	1	0	0	0	0
Combretum collinum ssp. Binderanum	0	1	0	1	0	0
C. molle	1	1	1	1	1	1
Commelina benghalensis	1	0	1	1	0	0
C. diffusa	1	0	1	0	1	0
C. erecta	0	0	0	0	0	1
C. petersii	0	0	0	1	0	0
Commiphora africana	1	1	1	0	1	0

Appendix 4 Continued

Species	Communities					
	1	2	3	4	5	6
C. bruceae	1	1	0	0	0	1
Commiphora habessinica	1	0	1	0	0	0
Commiphora schimperi	1	1	0	1	0	0
Corchorus olitorius	0	0	1	1	0	0
Crossandra nilotica	1	0	0	0	0	0
Crotalaria axillaris	0	0	0	0	1	0
C. incana	0	0	0	1	0	0
C. laburnifolia	0	0	0	1	0	0
C. pallida	1	0	0	0	0	0
C. pycnostachya	0	1	0	0	0	0
C. spinosa	1	0	1	0	0	0
Croton zambesicus	0	1	1	1	1	1
Cucumis prophetarum	0	0	0	1	0	0
Cyathula cylindrica	0	0	0	1	0	0
C. orthacantha	0	0	0	1	0	0
Cymbopogon excavatus	0	0	0	1	0	0
Cynanchum altiscandens	0	0	0	1	0	0
Cynodon dactylon	1	0	0	1	1	1
Cyperus alopecuroides	0	0	0	1	0	0
C. articulatus	1	0	0	0	1	0
C. assimilis	0	0	0	1	0	0
C. distans	1	0	0	0	0	0
C. dubius Rottb. ssp. Macrocephalus	1	1	0	1	0	0
C. fischerianus	0	0	0	1	0	0
C. haspan	0	1	0	0	0	0
C. nutans	0	0	0	0	1	0

Appendix 4 Continued

Species	Communities					
	1	2	3	4	5	6
C. rotundus	0	0	0	0	0	1
Cyphostemma adenocaule	1	0	0	0	0	0
Datura stramonium	0	0	0	0	0	1
Desmodium repandum	0	1	1	0	0	0
Dicrocephala chrysanthemifolia	0	0	1	0	1	0
Dichrostachys cinerea	1	1	1	1	1	0
Digitaria velutina	0	0	0	1	0	0
Dinebra retroflexa	0	0	0	1	0	0
Diospyros abyssinica	1	1	1	1	1	1
Dodonea angustifolia	0	1	1	0	1	1
Echinochloa colona	0	0	0	1	1	0
E. haploclada	1	0	0	0	0	0
E. pyramidalis	1	0	0	0	0	0
Ehretia cymosa	0	0	0	1	0	0
Elaeodendron buchananii	0	0	0	1	0	0
Eleusine indica	0	0	0	1	0	0
Endostemon tereticaulis	1	0	0	0	0	0
Enteropogon macrostachyus	1	0	1	0	0	0
Eragrostis aspera	1	0	0	1	0	0
E. cilianensis	0	1	0	0	0	0
Erianthemum dregei	1	0	0	0	0	0
Eriochloa fatmensis	0	0	0	1	0	0
Eriosema psoraleoides	1	0	0	0	1	0
Erythrina abyssinica	1	1	0	0	0	0
Euclea divinorum	0	1	0	0	1	1
Euphorbia kibwezensis	1	1	0	0	0	0

Appendix 4 Continued

Species	Communities					
	1	2	3	4	5	6
E. polyacantha	0	1	0	0	0	0
E. schimperiana	1	0	0	0	0	0
E. tirucalli	1	1	1	0	1	1
Ficus exasperata	0	0	0	0	0	1
F. ingens	1	0	0	0	0	0
F. sycomorus	0	0	0	1	0	0
F. thonningii	0	1	0	0	0	0
F. vasta	0	0	0	0	0	1
Fimbristylis bisumbellata	1	0	0	0	0	0
Flacourtia indica	0	0	0	1	0	1
Flaveria trinervia	1	0	0	0	0	0
Flueggea virosa	1	1	0	0	0	0
Galinsoga parviflora	0	0	0	0	0	1
Gardenia ternifolia	1	0	0	0	0	0
Glycine wightii	0	0	1	1	0	0
Gomphocarpus fruticosus	1	0	0	0	1	0
G. integer	0	1	0	0	0	0
G. purpurascens	1	0	1	0	0	0
Gomphrena celosioides	1	0	0	0	0	0
Grewia bicolor	1	1	1	1	0	1
G. erythraea	1	0	0	0	0	0
G. ferruginea	0	0	1	0	0	0
G. flavescens	0	1	0	0	0	0
G. tembensis	0	0	0	1	0	0
G. tenax	1	0	0	0	0	0
G. trichocarpa	1	0	0	0	0	0

Appendix 4 Continued

Species	Communities					
	1	2	3	4	5	6
G. velutina	1	1	1	1	0	1
G. villosa	1	0	1	1	1	0
Guizotia gillettii	0	0	0	1	0	0
G. scabra	0	0	0	0	0	1
Harrisonia abyssinica	1	1	1	1	1	1
Helichrysum schimperi	0	1	0	0	0	0
Heteropogon contortus	1	1	1	0	1	0
Hibiscus aponeurus	0	0	0	1	1	0
H. cannabinas	1	0	0	0	0	0
H. dongolensis	0	0	0	1	0	0
H. panduriformis	1	0	0	0	0	0
H. pyconostemon	1	0	0	0	0	0
Hippocratea africana	0	0	0	0	0	1
Hoslundia opposita	0	1	0	0	0	0
Hygrophila schulli	0	0	0	0	0	1
Hyparrhenia rufa	1	1	1	0	0	0
Indigofera schimperi	1	1	0	0	1	0
I. spicata	1	0	0	1	0	0
Ischaemum afrum	1	0	0	0	0	0
Jasminum floribundum	0	1	0	0	0	0
J. grandiflorum ssp floribundum	1	0	0	0	0	0
Justicia cufodontii	0	0	0	1	0	0
J. flava	1	1	0	0	0	0
J. ladanoides	1	0	0	1	0	0
Kalanchoe glaucescens	0	0	0	1	0	0
K. lanceolata	1	0	0	0	0	0

Appendix 4 Continued

Species	Communities					
	1	2	3	4	5	6
K. marmorata	1	0	0	0	0	0
Kleinia squarrosa	1	0	0	0	0	0
Lecaniodiscus fraxinifolius	1	1	1	1	1	1
Lactuca inermis	0	0	0	0	1	0
Laggera crispata	1	0	0	0	0	0
L. pterodonta	0	1	0	0	0	0
Leptochloa rupestris	0	1	1	1	0	0
Leucas glabrata	1	0	0	0	0	0
Leucas martinicencis	0	1	1	0	0	0
Ludwigia stolonifera	0	0	0	1	0	0
Lycopersicon	0	0	0	1	0	0
Maeruia angolensis	0	0	1	0	0	0
M. triphylla	1	1	1	1	0	0
Mariscus macropus	1	0	0	0	0	0
Maytenus undata	1	0	0	0	0	0
M. arbutifolia	0	0	0	0	1	0
Meineckia phyllanthoides	1	0	0	0	0	0
Melanthera abyssinica	1	0	0	0	0	0
Mollugo nudicaulis	0	0	0	0	0	1
Momordica friesiorum	0	0	1	0	0	0
M. pterocarpa	0	0	1	1	0	0
M. sessilifolia	0	0	0	1	0	0
Monanthotaxis parvifolia	0	1	0	1	0	0
Mystroxylon aethiopicum	0	1	0	0	1	1
Ochna inermis	0	1	0	0	0	0
Ocimum canum	0	1	0	0	1	0

Appendix 4 Continued

Species	Communities					
	1	2	3	4	5	6
O. urticifolium	0	0	0	0	0	1
Olea europaea	0	1	0	1	1	1
O. hochstetteri	0	0	0	1	1	1
Oncoba spinosa	0	0	0	0	0	1
Oncocalyx schimperi	1	0	0	0	0	0
Opuntia ficus-indica	0	0	0	1	0	0
Osyris quadripartita	1	1	1	0	1	0
Oxygonum sinuatum	0	0	0	0	1	0
Ozoroa insignis	0	0	0	0	0	1
O. pulcherrima	1	1	0	1	0	0
Panicum maximum	1	1	0	0	0	0
P. porphyrrhizos	1	0	0	0	0	0
P. repens	1	0	0	0	0	0
Pappea capensis	1	1	1	1	0	1
Paspalum scrobiculatum	0	0	0	0	1	0
Pavetta gardeniifolia	0	1	0	1	1	0
Pavonia melhanioides	1	0	1	0	0	0
P. propinqua	0	1	0	0	0	0
Pellaea calomelanos	0	1	0	0	0	0
Pennisetum clandestinum	0	0	1	0	0	0
P. ramosum	0	0	0	0	0	1
P. trachyphyllum	0	0	0	1	0	0
Pentarrhinum insipidum	0	0	0	0	1	0
Peristrophe paniculata	0	0	0	0	1	0
Perotis patens	1	0	0	1	0	0
Persicaria senegalensis	0	0	1	0	0	0

Appendix 4 Continued

Species	Communities					
	1	2	3	4	5	6
Phyllanthus ovalifolius	0	1	1	0	0	0
P. sepialis	0	0	1	0	0	0
Piliostigma thonningii	0	1	0	0	0	0
Plectranthus cylindraceus	0	0	1	0	0	0
P. longipes	1	0	1	0	0	0
Plumbago zeylanica	0	0	0	1	0	0
Polygonum plebeum	0	1	0	0	0	0
P. senegalense	0	0	1	1	0	0
Portulaca oleracea	0	0	0	0	0	1
Psiadia incana	0	1	0	0	0	0
Psydrax schimperiana	0	0	1	0	0	0
Pterolobium stellatum	1	0	0	1	1	1
Pupalia lappacea	0	0	0	0	0	1
Pycnostachys abyssinica	0	1	0	0	0	0
Rhamphicarpa heuglinii	0	0	0	0	1	0
Rhoicissus revoilii	0	0	1	0	1	0
R. tridentata	0	1	0	0	0	1
Rhus natalensis	1	1	1	1	1	0
R. vulgaris	1	0	0	0	0	0
Rhynchelytrum repens	1	0	0	0	0	0
Rhynchosia malacophylla	1	0	0	0	0	0
R. nyassica	0	1	0	0	0	0
Ricinus communis	0	0	1	1	1	0
Ruellia prostrata	0	0	0	0	0	1
Saccharum spontaneum	1	0	0	0	0	0
Salacia congolensis	0	0	0	1	0	1

Appendix 4 Continued

Species	Communities					
	1	2	3	4	5	6
Salvadora persica	1	0	0	0	0	0
Sansevieria abyssinica	1	1	1	1	1	1
S. ehrenbergii	1	1	1	1	0	1
S. phillipsiae	1	1	0	0	0	0
Sarcostemma viminale	1	1	0	0	0	0
Sclerocarya birrea	1	0	0	0	0	0
Sehima nervosum	0	1	0	0	0	0
Senna didymobotrya	0	0	1	0	0	0
S. occidentalis	1	0	0	0	0	0
S. petersiana	0	0	1	0	0	0
Seratia pumila	0	0	0	1	0	0
Sesbania goetzei	1	0	0	0	0	0
S. sesban	0	0	0	0	1	0
Setaria megaphylla	0	0	0	1	0	1
S. verticillata	0	0	0	0	1	0
Sida collina	1	0	0	0	0	0
Sida rhombifolia	1	1	0	1	0	0
Sida urens	1	0	0	0	0	0
Solanum glabratum	1	0	0	0	0	0
S. incanum	1	1	0	1	1	0
S. lanzae	1	0	0	0	0	0
Sorghum arundinaceum	0	1	1	1	1	1
Sphaeranthus steetzii	1	0	0	0	0	0
S. ukambensis	1	0	0	0	0	0
Sporobolus consimilis	0	0	0	0	0	1
S. festivus	1	0	0	0	0	0

Appendix 4 Continued

Species	Communities					
	1	2	3	4	5	6
S. ioclados	0	1	1	0	0	0
S. pyramidalis	1	0	1	0	1	0
Steganotaenia araliacea	0	1	1	0	0	0
Strychnos mitis	0	0	0	0	1	1
Stylosanthes fruticosa	0	0	0	0	1	0
Syzygium guineense	0	0	0	1	1	1
Tagetes minuta	0	0	0	0	1	0
Tamarindus indica	1	1	1	1	1	1
Teclea nobilis	1	1	1	1	1	1
Terminalia brownii	1	1	1	1	1	1
Themeda triandra	0	1	0	0	0	0
Tragia plukenetii	1	0	0	0	0	0
Tribulus terrestris	1	0	0	0	0	0
Tricalysia niamniamensis	1	1	0	0	0	0
Trichodesma zeylanicum	0	0	1	0	0	0
Triumfetta macrophylla	0	0	0	0	1	0
T. rhomboidea	0	0	0	0	1	0
Vangueria apiculata	0	0	0	1	0	0
Vernonia adoensis	1	0	0	0	0	0
Wissadula rostrata	1	0	0	0	0	0
Xanthium spinosum	1	0	0	0	1	0
X. strumarium	1	0	0	0	0	0
Ximenia americana	1	1	0	1	1	1
X. caffra	0	0	0	1	1	0
Zanthoxylum charybeum	1	1	1	0	0	0
Zaleya pentadra	0	1	0	0	0	0
Ziziphus mauritiana	1	0	1	1	0	0
Z. mucronata	1	1	1	1	0	1
Z. spina christi	1	1	0	0	0	0

Appendix 5 Altitude, position, slope and aspect of sample plots (quadrats) sampled from Abaya-Hamasa – Wolayta

Plot (Quadrat) No.	Altitude (m)	Position GPS - 48	Slope		Aspect (exposure)
			Degree	%	
1	1266	N06° 34.177' E037° 49.256'	30	57	NE
2	1310	N06° 34.076' E037° 49.19'	8	16	NE
3	1273	N06° 33.951' E037° 49.092'	12	21	SW
4	1283	N06° 33.820' E037° 48.989'	22	40	NE
5	1267	N06° 33.707' E037° 49.040'	5	8	N
6	1325	N06° 34.136' E037° 49.186'	27	53	NE
7	1291	N06° 34.206' E037° 49.244'	21	40	E
8	1251	N06° 34.273' E037° 49.299'	12	21	N
9	1257	N06° 34.258' E037° 49.324'	3	5	S
10	1272	N06° 34.307' E037° 49.353'	5	8	SW
11	1280	N06° 33.967' E037° 49.397'	5	8	N
12	1255	N06° 34.005' E037° 49.438'	18	32	SE

Appendix 5 Continued

Plot (Quadrat) No.	Altitude (m)	Position GPS - 48	Slope		Aspect (exposure)
			Degree	%	
13	1233	N06° 33.807' E037° 49.493'	3	5	S
14	1261	N06° 33.936' E037° 49.451'	19	35	NE
15	1262	N06° 33.763' E037° 49.493'	3	5	SW
16	1250	N06° 33.705' E037° 49.451'	25	47	SE
17	1234	N06° 33.488' E037° 49.460'	3	5	NE
18	1247	N06° 33.417' E037° 49.456'	3	5	SE
19	1257	N06° 33.436' E037° 49.483'	14	25	N
20	1234	N06° 33.359' E037° 49.417'	15	27	NW
21	1225	N06° 33.304' E037° 49.421'	25	47	NE
22	1227	N06° 33.436' E037° 49.437'	10	19	SW
23	1220	N06° 33.243' E037° 49.442'	11	20	SW
24	1216	N06° 33.200' E037° 49.476'	17	31	N

Appendix 5 Continued

Plot (Quadrat) No.	Altitude (m)	Position GPS - 48	Slope		Aspect (exposure)
			Degree	%	
25	1213	N06° 33.152' E037° 49.488'	11	19	SE
26	1187	N06° 31.751' E037° 49.999'	6	12	SE
27	1184	N06° 31.915' E037° 50.062'	4	9	NE
28	1221	N06° 32.120' E037° 49.809'	2	4	NE
29	1222	N06° 32.915' E037° 49.826'	10	18	NE
30	1258	N06 ° 33 .182' E037 ° 49.636'	8	14	SE
31	1241	N06 ° 33.871' E037 ° 50.293'	26	50	E
32	1228	N06 ° 33.771' E037 ° 50.268'	25	47	E
33	1238	N06 ° 33.700' E037 ° 50.243'	15	27	NE
34	1234	N06 ° 33.657' E037 ° 50.276'	1	2	N
35	1257	N06 ° 33.470' E037 ° 50.132'	26	50	E
36	1231	N06 ° 33.309' E037 ° 50.105'	1	2	N

Appendix 5 Continued

Plot (Quadrat) No.	Altitude (m)	Position GPS - 48	Slope		Aspect (exposure)
			Degree	%	
37	1236	N06° 32.865' E037° 50.467'	4	7	E
38	1188	N06° 33.177' E037° 50.625'	1	2	E
39	1223	N06° 33.254' E037° 50.515'	6	11	N
40	1239	N06° 33.451' E037° 50.519'	4	8	N
41	1241	N06° 33.407' E037° 50.727'	3	5	NE
42	1248	N06° 34.158' E037° 50.442'	1	2	SE
43	1252	N06° 34.259' E037° 50.533'	1	2	W
44	1261	N06° 34.215' E037° 50.600'	1	2	SW
45	1251	N06° 34.272' E037° 50.457'	28	55	SW
46	1249	N06° 34.313' E037° 50.575'	2	4	NW
47	1256	N06° 34.407' E037° 50.532'	3	5	NE
48	1258	N06° 34.406' E037° 50.537'	3	5	SE

Appendix 5 Continued

Plot (Quadrat) No.	Altitude (m)	Position GPS - 48	Slope		Aspect (exposure)
			Degree	%	
49	1277	N06° 31.241' E037° 46.621'	9	17	SE
50	1222	N06° 31.103' E037° 46.779'	1	2	NW
51	1410	N06° 27.404' E037° 44.042'	4	8	N
52	1294	N06° 37.368' E037° 52.169'	12	21	W
53	1307	N06° 37.198' E037° 51.919'	27	53	NW
54	1307	N06° 36.384' E037° 51.245'	1	2	NE
55	1309	N06° 36.270' E037°50.837'	1	2	N

Appendix 6 ANOVA-One-way analysis of variance of environmental variables

		Sum of Squares	*df*	Mean Square	F	Sig.
Altitude (m)	Between groups	17893.535	5	3578.707	3.047	.018
	Within groups	57542.574	49	1174.338		
	Total	75436.109	54			
Slope (°)	Between groups	405.030	5	81.006	.969	.446
	Within groups	4097.770	49	83.628		
	Total	4502.800	54			
PH	Between groups	2.187	5	.437	2.073	.085
	Within groups	10.340	49	.211		
	Total	12.526	54			
EC (mmhos-cm)	Between groups	2.959	5	.592	.710	.619
	Within groups	40.829	49	.833		
	Total	43.788	54			
TN	Between groups	7.375	5	1.475	2.736	.029
	Within groups	26.413	49	.539		
	Total	33.788	54			
% Sand	Between groups	67.155	5	13.431	.062	.997
	Within groups	10588.227	49	216.086		
	Total	10655.382	54			
% Clay	Between groups	170.476	5	34.095	.274	.925
	Within groups	6105.269	49	124.597		
	Total	6275.745	54			
% Silt	Between groups	103.413	5	20.683	.411	.839
	Within groups	2468.587	49	50.379		
	Total	2572.000	54			

Appendix 7. List of widely distributed species and the quadrats (plots) in which they occur

Species Scientific name	Quadrats (plots)
Acacia brevispica	2, 3, 6, 7, 11, 12, 14, 15, 16, 19, 21, 22, 24, 29, 32, 34, 35, 37, 38, 39, 42, 43, 44, 45, 46, 48, 52, 53
Acacia tortilis	6, 9, 10, 13, 15, 29, 32, 36, 37, 42, 44, 45, 46, 47, 48, 50, 51, 54
Acalypha fruticosa	2, 7, 9, 10, 11, 16, 17, 19, 23, 24, 29, 32, 36, 37, 39, 41, 42, 44, 45, 46, 50, 52, 54
Baphia abyssinica	8, 9, 13, 14, 17, 18, 19, 21, 22, 23, 24, 25, 33, 38, 39, 46, 48
Cissus quadrangularis	2, 19, 21, 24, 27, 28, 30, 32, 34, 35, 36, 37, 38, 39, 42, 43, 44, 45, 47, 48, 52, 53
Combretum molle	1, 2, 3 , 6, 7, 8, 9, 11, 12, 13, 16, 20, 33, 35, 40, 41, 42, 46, 47, 48, 49, 50, 51, 52, 53
Croton zambesicus	6, 7, 8, 9, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 38, 39, 42, 46, 48, 50
Dichrostachys cinerea	1, 2, 3, 9, 10, 11, 12, 13, 19, 26, 28, 29, 32, 34, 35, 36, 37, 38, 40, 41, 42, 44, 46, 49, 50, 51
Diospyros abyssinica	7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 20, 21, 22, 23, 24, 25, 48, 50
Euphorbia tirucalli	10, 11, 12, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 38, 42, 46, 53, 54
Grewia bicolor	2, 3, 6, 9, 10, 12, 15, 19, 21, 23, 27, 30, 32, 34, 35, 38, 39, 41, 42, 43, 44, 45, 46, 47, 48, 51, 52, 54, 55
Grewia velutina	1, 2 ,4, 10, 12, 19, 21, 23, 28, 29, 30, 31 32, 35, 36, 37, 40, 41, 45, 46, 48, 51, 53, 54
Harrisonia abyssinica	1, 2, 3, 6, 7, 8, 10, 11, 13, 14, 17, 18, 20, 21, 24, 27, 28, 29, 30, 31 32, 34, 36, 39, 40, 43, 46, 47, 48, 49, 51, 54
Lacaniodiscus fraxinifolius	7, 8, 9, 11, 13, 14, 15, 16, 49, 22, 23, 30, 33, 38, 39, 48, 50, 51

Appendix 7 Continued

Species Scientific name	Quadrats (plots)
Maeria triphylla	2, 5, 6, 7, 9, 10, 13, 15, 26, 27, 30, 31, 34, 36, 39, 40, 42, 44, 46, 52
Pappea capensis	2, 3, 6, 7, 12, 15, 17, 23, 27, 29, 30, 31, 35, 40, 49, 51
Rhus natalensis	1, 5, 7, 9, 10, 12, 13, 14, 23, 26, 27, 28, 29, 30, 31, 32, 34, 35, 36, 37, 38, 40, 41, 42, 45, 46, 47, 49, 51, 55
Sansevieria abyssinica	4, 6, 15, 19, 21, 25, 27, 38, 39, 42, 46, 47, 48, 52, 53
Sansevieria ehrenbergii	4, 5, 15, 28, 29, 32, 34, 37, 38, 40, 41, 42, 43, 44, 45, 46, 47, 48, 53
Tamarindus indica	7, 11, 12, 13, 15, 21, 24, 27, 29, 31, 32, 35, 37, 39, 40, 41, 49, 51
Teclea nobilis	3, 7, 8, 9, 10, 11, 12, 14, 17, 19, 20, 22, 23, 24, 25, 27, 29, 32, 33, 35, 38, 39, 41, 42, 46, 47, 48, 50, 51, 52, 53
Terminalia brownii	1, 4, 6, 7, 9, 12, 13, 14, 15, 16, 17, 19, 21, 22, 23, 24, 29, 30, 40, 42, 49, 50, 51
Ximenia americana	3, 6, 10, 26, 27, 30, 32, 34, 37, 40, 42, 47, 49, 50, 51
Ziziphus mucronata	3, 9, 10, 11, 12, 13, 14, 15, 17, 20, 27, 28, 29, 30, 31 34, 35, 36, 37, 40, 43, 44, 48, 49