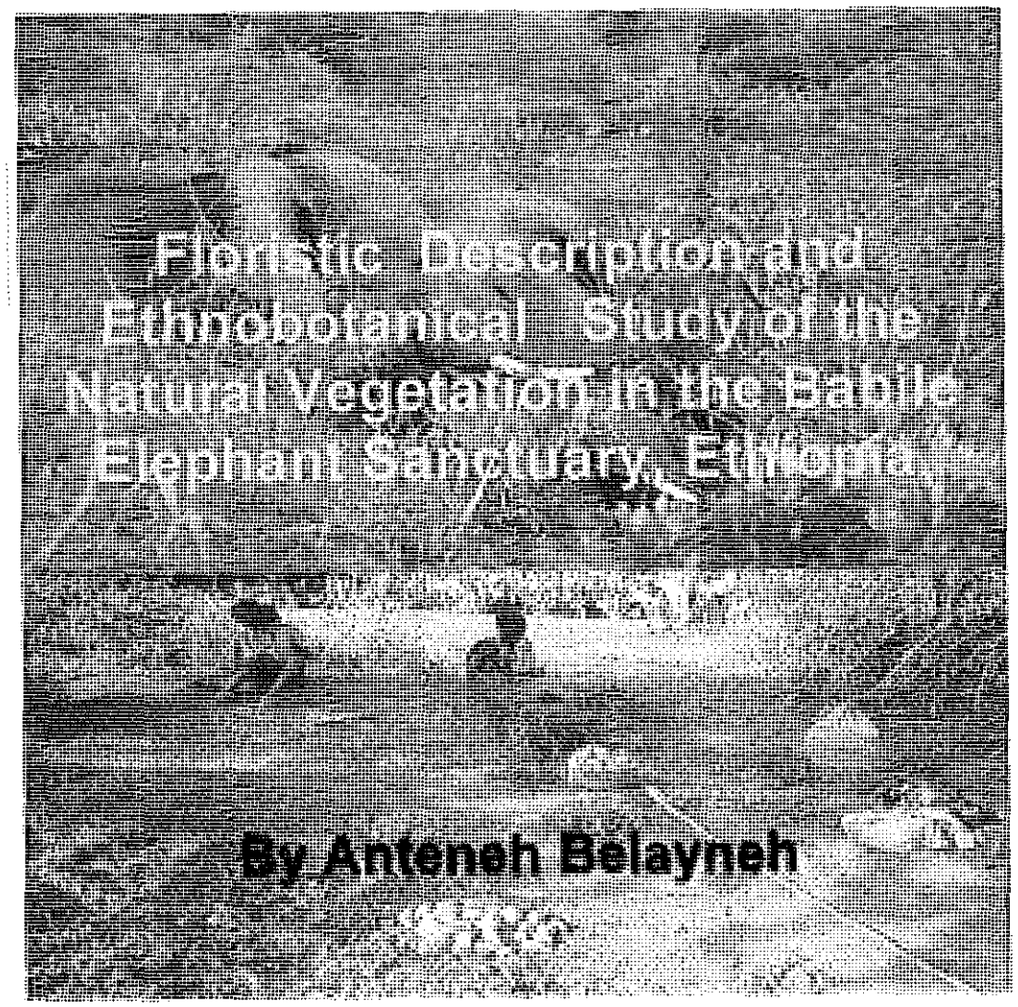
Addis Ababa University

School of Graduate Studies

Biology Department



Addis Ababa

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Dedication

This work is dedicated to my kids Ililina and Liyu.

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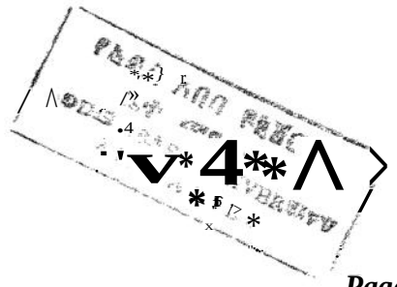

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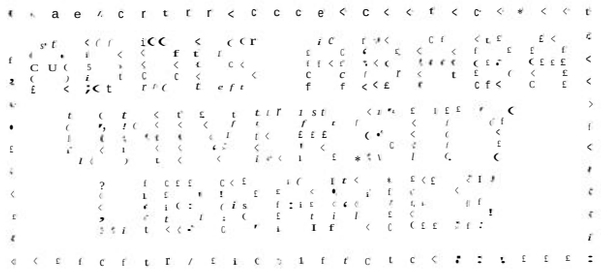
Abbreviations and Acronyms

BES	Babile Elephant Sanctuary
CAP	Community Analysis Package
CSA	Central Statistical Agency
EFAP	Ethiopian Forest Action Program
EWNHS	Ethiopian Wildlife and Natural Histoiy Society
FAO	Food and Agricultural Organization of United Nations
IUCN	International Union for the Conservation of Nature
MfM	Menschen for menschen
NMSA	National Metrological Service Agency
Or	Oromoo language
PRA	Participatory Rural Appraisal
RPSUD	Research Program for Sustainable Use of Dryland Biodiversity
S	Somali language
SAREC	Swedish Agency for Research and Cooperation with Developing Countries
SIDA	Swedish International Development Agency
SPSS	Statistical Package for Social Studies
SPSS	Statistical package for Social Science
TWINSPAN	Two Way INdicator SPecies Analysis
UNEP	United Nations Environmental Program
WCMC	World Conservation Monitoring Center

Abstract

A floristic description and ethnobotanical study of the naturahvegetation was carried out between September 5, 2005 and June, 2006 in the Babile Elephant Sanctuary (BES), which was established in 1970, in the semi-arid region of Ethiopia. Stratified sampling design was used and 75 quadrats each 400 m^2 were analyzed. A total of 237 plant species in 155 genera and 57 families were identified. Fabaceae was represented by the highest number of species (36 species = 15.1%), followed by Poaceae (19 species = 8.0%) and Asteraceae (15 species = 6.3%). Using TWINSPAN program six community types were identified. These are: I. *Tamarhuhts indicci* II. *Acacia robusta* III. *Acacia seyal -Balanites aegyptiaca IV. Acacia senegal-Acalypha fruticosa V. Terminalia brownii-Boswellia neglecta* and *VI. Acacia bussie-Grewia tenax* community types. The Biodiversity professional version 2.0 soft ware result shows the six communities differ in species diversity where the smallest was 2.1 and the highest was 3.44. The total diversity and evenness of the study area were 3.55 and 0.72 respectively. SPSS program was used to analyze the density of woody species. About 67 woody species (22 tree, 36 shrubs and 9 climber species) were identified having a total basal area of 17.8 m^2/ha. The mean density of these woody species was 385 ± 114.2 (S.E.) individuals ha^{-1} where the mean density of trees was 32 ± 9.96, shrubs 619 ± 203.3 and climbers 315 ± 103.4 individuals ha^{-1}. Ethnobotanical information was collected from 40 informants where 15 are key informants selected by systematic sampling method. Semi-structured interview was administered both in Oromoo language and Somali language and guided field walk was conducted to gather ethnobotanical information. The local community make use of 32 species as food plants, 43 for human medicinal plants, 59 for forage, 20 veterinary medicine, 28 for construction and craft, 18 for fuel (firewood and charcoal), 8 for spice and condiments, 8 as cash crops (where plant products have market value) and 38 species for other uses. Preference ranking result show *Opuntia Jicus-indica, Tamarindus indica* and *Balanites aegyptiaca* ranked 1 up to 3 as a food plants and the direct matrix ranking result show *Tamarindus indica, Berchemia discolor* and *Balanites aegyptiaca* ranked 1 up to 3 as a multipurpose tree species. Anthropogenic impact was assessed and arbitrary number was assigned 1 up to 5 from the lowest to the highest threat. Then agriculture scored 5, human settlement and overgrazing 4, charcoal making and tree cutting 3, invasive species 2, and honey collection 1. Invasive species like *Lantana camara* and *Parthenium hystrophorus* are the other threat where *L. camara* was recorded in 43 quadrats having the density 2794.6 individuals ha^{-1}. In general, as part of the country's remaining vegetation cover and as part of the habitat of the only living representative individuals of the elephant *(Loxodonta Africana Orleansi)* as well as a variety of other animals and as to the benefit of the local community, the BES should be afforded the highest protection possible as a matter of urgency before it is too late.



1. Introduction

1.1. Background and Justification

Vegetations are the most obvious physical representation of ecosystems (Kent and Coker, 1992). These ecosystems are degraded and species and genetic diversity are being lost at an alarming and unprecedented rate (Farah, 1997). The decline of ecosystem is one of the most serious environmental issues facing humankind today. The crises are more severe in the dryland environments. The present estimated area of drylands in Ethiopia is over 75 million ha, about 66% of the total area of the country (EFAP, 1994). Of this, 25 million ha is covered with woodlands and bushlands. This implies that the largest vegetation resource of the country is found in the dryland areas. These enormous areas of dryland vegetation resources are facing serious problems of degradation.

The dryland ecosystems are unique and unexpectedly biodiversity rich (WCMC, 1992; IUCN, 1999). Having these biodiversity potential and supporting a population of about 20% of the world total, the drylands are rapidly being degraded due to population growth, deforestation, overgrazing, cropping of marginal lands, inappropriate irrigation and bush encroachment (FAO, 2000). The UNEP has found that at least 75% of the arid and semi arid regions productive lands have already moderately desertified or lost more than 25% of the original productivity (Kuchar, 1995). The problem would particularly severe in developing countries. Especially in Ethiopia ecosystem degradation include protected areas.

Ethiopia is facing severe degradation in both high lands and lowlands because of the current population increase of around 3% per year. According to Tamirat Bekele (1994), currently most of the remnant forest of the country exist in patches and are in a secondary state of development. Land resource scenarios indicate that if present trends continue, Ethiopia will have an overall crisis involving livestock grazing land and an arable land in about 25 years (Hurni, 1992). Different studies suggested the continuation of land degradation.

Therefore, it is important to establish a system of protected areas or reserves to conserve biodiversity, because the demands for higher yields to feed the growing population are currently fulfilled by increasing the areas of cultivable land, a practice that is not sustainable.

IUCN (1990) reviewed over all biodiversity levels of Ethiopia, which are relatively high in many animal groups and plants. There is a relatively high degree of endemism as much as 12% in plants, 11.4% in mammals, 2.7% in birds and 4.5% in reptiles. Most of the the endemic species are found in the Ethiopia drylands, as part of the Somalia-Masai Regional Centre of Endemism. As stated by Teweldeberehan Gebre Egziabher (1990), the drylands of Ethiopia are reportedly biodiversity rich and any vegetation change may result in species decline or loss. For these and other reasons dryland monitoring and assessment is essential in order to plan and implement conservation measures.

Lack of integration of the local people living around the natural vegetation areas in the conservation efforts, and absence of law enforcement system are the major constraints to the overall conservation efforts in Ethiopia (Feyera Senbeta and Demel Teketay, 2003). Because of the increasing human pressure on natural habitats, human use of the natural vegetation is becoming almost unavoidable. Nowadays, many conservationist and policy makers have recognized the feeling of local communities and seemingly found out that conservation of the natural ecosystems could not be successful without considering the communities that had historically occupied these areas (Feyera Senbeta and Demel Teketay, 2003). Traditional societies of the world accumulated a wealth of traditional knowledge as a result of prolonged interaction with the natural world. These knowledge system remained fundamental to their physical, spiritual and social security. As stated by Martin (1995), ethnobotanical information is basic for conservation and community development activities.

Establishment of protected areas is vital for the conservation of diverse native species with in the areas. These activities were undertaken for the sake of education, research, and recreation. Moreover, these areas provide such essential items as fuel wood, building

materials, forage, traditional medicines, and wild foods. Protected areas cover approximately 14% of the country's surface area (Hillman, 1993). Several of Ethiopia's protected areas exist on paper only, while others have declined in size or quality (Hillman, 1993).

Babile Elephant Sanctuary in the semi-arid region of east Ethiopia is one of the protected areas, which is highly declined in size and quality. As a result of mass influx of a large number of farmers and their domestic stocks from the east and north, the home range of elephants of Babile has shrunk by about 65.5% since 1976 (Yirmed Demeke *et ah*, 2006). The sanctuary was established to protect the only known population of the isolated, ecologically distinct subspecies *Loxodonta africcma orleansi* (Barnest *et al*., 1999). Although it has been designated as the largest sanctuary (6984 km^2) in the country there was no any systematic ecological and ethnobotanical study conducted since its establishment.

The valleys formed by the Erer, Daketa, Gobele and Fafem rivers are significant physical features within the sanctuary (http://www.birdlife.org). The Daketa, Gobele and Erer Valleys are the three large areas with natural vegetation (*Acacia* woodland, riverine forest, shrub and bushlands) in the sanctuary. The Fafem river valley was apparently once covered with dense bushland, but this has been cleared or much reduced, as more and more agro-pastoralists have taken up crop cultivation (http://vAvw.birdlife.org). The other three valleys are highly impacted by human interference. Therefore, there is a big danger of loss of biodiversity and indigenous knowledge in the study area.

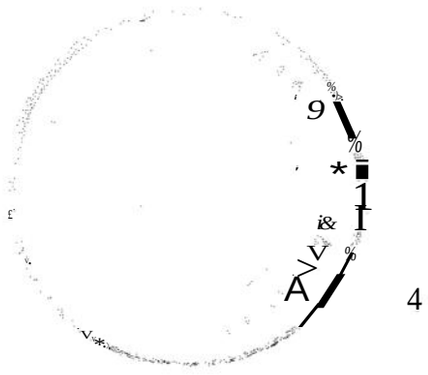
This study was carried in the Erer valley, which is the largest part of the Babile Elephant Sanctuary. This valley is the most extensive part of the sanctuary where it is currently subject to increasing settlement pressure. Both the human and livestock population have increased dramatically. The Erer valley, including Erer 'guda' and Erer 'tika' valleys, has the densest vegetation stand in the entire sanctuary (Stephenson, 1976). The vegetation of the area was probably *Acacia* woodland and grassland on the plain, and *Acacia* bush land

on the slopes (Stephenson, 1976). However, no systematic study of the plant life of the area has ever been carried out (http://www.birdlife.org).

Since the Erer valley is a borderline between the eastern Hararge highland to the east and southeast lowlands, conservation of such area may prevent the current rapid desertification process in the area. More over it supports the Babile Elephant Sanctuary, which is the natural home for endemic elephant subspecies known as *L. africcma orleansi*, which is highly endangered currently (Barnest *et a!.,* 1999). In his discussion on the natural resources of Ethiopia, Tewoldebrehan Gebre Egziabher (1989) noted that to pinpoint areas of conservation of plant and animal resources in Ethiopia, inventories of conservation areas concerned should be carried out. Although the Erer valley is given a sanctuary status, there is no work on its flora. Friis (1987) indicated that the sanctuary is of special interest from a plant conservation point of view and deserves more attention from botanically inclined conservationists.

Ethiopia has the fifth largest flora in tropical Africa. About 7000 species of higher plants are estimated to occur and most of these are known for their uses (Tewolde Berehan Gebre Egziabher, 1991). Thus, more work is expected in plant collection, vegetation description and ethnobotanical studies. However, little emphasis is given to ethnobotanical studies, though ethnobotanical information is important for genetic resource conservation and utilization. Only a few researches have been conducted. Hence, there is a need for more ethnobotanical studies as the country consists of diverse groups of people with diverse environment and associated indigenous knowledge.

Plant collections, vegetation description and ethnobotanical study should be carried out in order to understand the status and implement proper management, conservation and sustainable use of the vegetation in the Babile Elephant Sanctuary.



1.2. Objectives of the study

1.2.1. General objective

The main objective of this study is to document the floristic composition and community types and assess the traditional uses of plants by local communities for proper management, conservation and sustainable use of the natural vegetation in the study area.

1.2.2. Specific objectives

- To identify and document the plant species.
- To determine the community types.
- To determine plant species richness, evenness, diversity, and abundance.
- To analyze the regeneration status of trees.
- To document indigenous knowledge on the use of plants and use categories.
- To identify the multipurpose woody species.
- To identify the major anthropogenic impacts in the sanctuary and recommend possible conservation measures.

1.3. Research questions

i. What are the plant species in the study area?
ii. What are the major plant communities?
iii. How are the richness, diversity and abundance of the plant species?
iv. How is the regeneration status of trees?
v. What are the traditional uses of plants by the local community?
vi. Which are the major plant species used by the local communities and multipurpose trees and shrubs in the study area?
vii. What are the major threats to the study area?

2. Literature Review

2.1. Dryland vegetation in Ethiopia

Drylands are extremely diverse in terms of their land form, soils, flora, fauna, water balances and human activities (UNEP, 1992). They constitute about one third of the earth's surface. Drylands are areas where rainfall is low, variable, often unreliable, and generally unevenly distributed throughout the year (UNEP, 1992; IUCN, 1999). Drylands cover hyper-arid, arid, semiarid and dry sub-humid ecosystems having low P/PET ratio (where P is mean annual precipitation and PET is the mean potential evapotranspiration of the area) (Menault and Cesar, 1985; IUCN, 1999). Drylands have highly seasonal rain fall regimes with significant inter-annual variability and mean annual precipitation values which vary from about 800 mm in summer rainfall areas to 250 mm in winter regimes (IUCN, 1999).

Drylands occur on all continents and are estimated to cover approximately 61 million square kilometers, excluding cold climate regions (UNEP, 1992; IUCN, 1999). Dryland vegetation type varies with annual rainfall fluctuations. Vegetation cover is characterized by low plant density and coverage, little variation and plant productivity per unit area. Generally, biodiversity as represented by species richness is found to decline with increasing aridity for most taxa. However, dryland ecosystems are unique and unexpectedly biodiversity rich (WCMC, 1992; IUCN, 1999).

Dryland vegetation patterns are classified mainly based on the height and density of the principal growth forms and species composition. These vegetation types include bushes, shrubs, succulent, thorny or leafless shrubs, steppe and grasslands, savannas and scrub vegetation. The native vegetation is represented by a variety of species, such as grasses, other herbs, forbs, shrubs and trees. Semi arid regions include steppe and grasslands with some savanna and tropical vegetation (UNEP, 1992; IUCN, 1999). The majority of the semi-arid ecosystem is *Acacia* woodlands. Forests usually exist in areas where climate is humid or with some constant supply of ground moisture available, which is not the case in most drylands (IUCN, 1999).

Drylands cover about 60% of the Ethiopian land surface where 12% of human and 20% of livestock population is living (CSA, 1995; Leipzig, 1996). White (1983) describes the driest area of Eastern Africa as the "Somalia-Masai Regional Center of Endemism", the predominant physiognomic region in East Africa. This phytochorion includes eastern and south eastern Ethiopia with the exception of mountainous areas, most of Kenya between the highlands and the coastal belt, the dry lowlands of north and central Tanzania, most region of Somalia and Eritrea, SE Sudan and NE Uganda (White, 1983). There are about 2500 plant species, of which, half are endemic, and there are about 50 endemic genera. *Acacia-Commiphora* vegetation type is the dominant type in Somalia-Masai Regional Center of Endemism. One major centre of endemism is the Ogaden lowland, SE part of Ethiopian lowland; with several endemic genera (Friis, 1982). Babile Elephant Sanctuary is part of this region expectedly with several endemic genera and rich in biodiversity.

Drylands in Ethiopia include rangelands, wooded grasslands, scrublands and bushlands. Bushlands and shrublands contribute 21.4% while grasslands are 30.5% of the total landmass in Ethiopia (CSA, 1995). The earliest vegetation classification was that of Pichi-Sermolii (1957) which recognized 23 vegetation types in Ethiopia. Recent vegetation classification studies have divided Ethiopian vegetation into nine major types (Zerihun Woldu, 1999).The vegetation of Ethiopia have been classified and described by several authors. These include Sebsebe Demissew (1988); Zerihun Woldu (1985); Tewolde Berehan Gebre Egziabher (1988); Tamirat Bekele (1994); Sebsebe Demissew *et al.,* (1996); Demel Teketay (1999); Friis and Sebsebe Demissew (2001). According *to* White (1983), *Acacia-Commiphora* deciduous bushland and thicket, semi-desert and desert vegetation (Sebsebe Demissew *et al.,* 1996), riparine vegetation (Demel Teketay, 1999) are found in the study area, which is part of the Ogaden region and Eastern Hararge lowlands.

Some dryland vegetation types are discussed here after:

2.1.1. *Acacia-Commiphora* deciduous bushland and thicket

Acacia-Commiphora deciduous bushland and thicket is the climax over the greater part of the Somalia-Masai region. Characteristically it is s dense bushland, 3-5 meters tall with

scattered emergent trees up to 9 m (White, 1983). Locally it is impenetrable and then forms thickets. The dominant *Acacia* species and some of the *Commiphora* species are spiny and impede progress even in the more open types except along game and cattle tracks. In higher rainfall areas, especially on rocky hills, the emergent trees occur closer together and are a little taller, though scarcely even more than 10 m. Greenway, in White (1983) refers to these variants as woodland. Although there is appreciable variation in floristic composition, species of *Acacia, Commiphora, Capparis* and *Grewia* are nearly always present. Most species are deciduous. The majority of these are multiple-stemmed bushes or small bushy trees which are branched near the base.

2.1.2. *Acacia-Commiphora* (small-leaved deciduous) woodland

This vegetation is found mainly between the altitudes of 500 m and 1900 m, with average annual temperatures of 19 to 27^{0}C and annual rain fall between 410 mm and 820 mm (Ensermu Kelbessa *et al.*, 1992). The characteristic plant species in this vegetation type include drought tolerant trees and shrubs; *Acacia tortilis, Acacia mellifera, Balanites aegyptiaca*, species of *Acalypha, Aerva, Barleria, Capparis, Combretum, Terminalia*, etc are included (Demel Teketay, 1999; Friis and Sebsebe Demissew, 2001). This vegetation type occurs mainly in southern and eastern parts of the country and the rift valley (Demel Teketay, 1999).

2.1.3. Riparian vegetation

This vegetation type is found only on the river banks. Plant species like, *Acacia robusta, Tamarindus indica, Acokanthera schimperi* and *Capparis tomentosa* are the characteristic species on the banks of the rivers in the Somalia-Masai Center of Endemism (White, 1983).

2.2. Concept of vegetation description

Vegetation is characterized by the link between individual species distribution patterns, their occurrence in landscape features, and the distribution of the landscape features (Walter, 1971). Before any serious or detailed work can be commenced in an area, it is

necessary to know what species are present, what their distribution is and what is the relative degree of abundance of each species (Kent and Coker, 1992). Because vegetation is the most obvious physical representation of an ecosystem. The objective of vegetation description is to enable people other than the observer to build a mental picture of an area and its vegetation and to allow the comparison and ultimate classification of different units of vegetation (Kent and Coker, 1992). When ecologists talk about different ecosystem types, they usually equate these with different vegetation types. The building blocks of vegetation are individual plants. Therefore, species list of the area is part of vegetation description. Each plant is classified according to a hierarchical system of identification and nomenclature using carefully selected criteria of physiognomy and growth form (Kent and Coker, 1992).

The use of vegetation description are in the recognition and definition of different vegetation types and plant communities known as the science of phytosociology; the mapping of vegetation communities and types; the study of relationships between plant species distributions and environmental controls; and the study of vegetation as a habitat for animals, birds and insects (Kent and Coker, 1992). Information on vegetation may be required to help to solve an ecological problem; for biological conservation and management purposes; as an input to environmental impact statements; to monitor management practices or to provide the basis for prediction of possible future changes. According to Groen (1994), floristic data are relevant for establishing the present situation for environmental impact assessment and for monitoring changes in ecosystem quality in terms of changing species composition.

Plants community structure and function are manifestations of a complex array of interactions, directly or indirectly by community members altogether. Understanding their composition, stand structure, dynamics, and spatial distribution of vegetation for any landscape requires a solid understanding of the site conditions, disturbance regimes, history and processes of the landscape ecosystems of which they are an inherent part (Krebs, 1989). Vegetation as a component of ecosystems displays the effects of other environmental condition and historic factors in an obvious and easily measurable manner.

Thus, careful analysis of vegetation used as a means of revealing useful information about aspects of an ecosystem (Goldsmith *et al.,* 1986). Vegetation study could also help and promote to select and employ the appropriate conservation and management plan for sustainable use of ecosystem (Kershaw, 1973).

Different methodologies are used in vegetation ecology. One of these is stratification. According to Kent and Coker (1992), the principle of stratification is that, the vegetation of the area under study is divided up before samples are taken.

2.3. Plant Communities

When an ecologist stands on a hilltop and surveys a landscape dominated by natural or semi-natural vegetation in any part of the world, the main differences in pattern visible in the landscape will be those of plant communities (Kent & Coker, 1992). As he stated, the main differences will be made on the basis of growth forms like woodlands as opposed to scrub or grasslands.

The plant community can be defined as the collection of plant species growing together in a particular location that show a definite association or affinity with each other (Kent & Coker, 1992). Therefore, plant species are the building blocks of the plant communities that together constitute the vegetation of the different regions (Walter, 1971). As stated by Mueller-Dombois and Ellenberg (1974), a plant community can be understood as a combination of plants that are dependent on their environment, influence one another, and modify their own environment. He further stated that, the floristic composition of vegetation includes all species occurring within a plant community however, most plant communities consist of so many species that it is not practical to discover all species within a community. Therefore, it is common to use dominant species in naming plant communities.

2.4. Species diversity

Diversity in ecological research could refer to species, habitat or genetic diversity including variability between species, habitats, and individuals respectively (Magurran, 1988). Accordingly, plant diversity denotes the variety of life forms, the ecological roles they perform and the genetic diversity they contain (Magurran, 1988). Understanding the variation in plant species diversity patterns at different scales is an important topic of concern both for ecological explanations and for effective conservation design (Urban *et al.,* 2000). More over, patterns of plant species diversity have often been noted for prioritizing conservation activities because they reflect the underlying ecological processes that are important for management (Lovett *et al.*, 2000).

Species diversity could be viewed from different approaches in terms of alpha, beta and gamma diversity. Alpha diversity refers to the diversity of species within a particular habitat or community. Beta diversity is a measure of the rate and extent of change in species along a gradient from one habitat to another; it is between habitat diversity that measures turnover rate. Gamma diversity on the other hand, is the diversity of species in comparable habitats along a geographical transects and is dependent on the alpha and beta diversity.

A large number of indices of diversity have been devised, each of which seeks to express the diversity of a sample by a single number (Kent & Coker, 1992). Of the various indices, the most frequently used is the simple totaling of species numbers to give species richness (Magurran, 1988). Species richness is the simplest concept of species diversity implying the number of species in a community. Species richness is a biologically appropriate measure of alpha diversity and is usually expressed as number of species per sample area (Whittaker, 1972). Species evenness measures the equity of species in a given sample or community (Magurran, 1988). Species diversity is measured by recording species richness and evenness. Of the indices that combine species richness with evenness, probably the most widely used is the Shannon diversity index (Kent & Coker, 1992).

2.5. Protected areas and benefits

A protected area is a geographically defined area, which is designated or regulated and managed to achieve specific conservation objectives (UNEP, 1992). According to IUCN 1994, protected areas are defined as areas of land or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other affective means. Even though the concept of protected areas and the protected area network have evolved long back, establishing conservation areas was not a thrust programme of government until the late 1970s (IUCN, 1994). Hence, it is established that protected conservation area network, irrespective of the region of occurrence would have global significance in improving the environmental quality. Protected areas serve as major centers of biodiversity conservation, globally.

Protected areas can help meet societies evolving needs provided that they are well protected and conserved (McNeely *et al.,* 1984). They maintain those ecological processes that are essential for the continuation of life and safeguard habitats critical for sustainable use of species. They preserve the diversity of species and the genetic variation within them, thereby preventing irreversible damage to our natural heritage (Demel Teketay, 1995). They provide opportunities for scientific research, education, and training. They also provide places for recreation as well as tourism, and serve the spiritual and cultural needs of people by securing the wilderness and sacred areas on which so many draw for aesthetic, emotional, and religious nourishment.

Protected areas are established with different objectives. Each protected area is established with different purposes and use patterns. Wildlife sanctuaries are one category of protected areas. Wildlife sanctuaries are established so as to conserve various habitat types with its biotic communities in the natural set up (IUCN, 1990). The idea is to conserve representative physical and environmental features of each region or state during this process. Limited human activities may be permissible in wildlife sanctuaries particularly in connection with resource use.

The extent of protected areas was less in the first half of the 20th century. It was during the 1980s that a good proportion of the natural habitat was added to the protected area system, globally (IUCN, 1994). As present, there are nearly 10,000 protected areas, recognized by the IUCN Commission on Parks and Protected Areas. The extent of these areas is almost 147 million square kilometers (IUCN, 1994). Region-wise, protected areas contribute from 2-8% of the land area in North Africa and the Middle East to 12.6% in North America. At present, it is in protected areas, where the world's biological diversity is concentrated and conserved. Most of these are in the tropical realms where the world's human population is also concentrated and hence the threat to protect the protected areas is severe. Although conservation of natural resources including wildlife population is stressed as a mandatory agenda of development, only few among the developing tropical nations have so far set aside at least 10% of the total geographic area under protective cover (IUCN, 1999).

Ethiopia, located in the horn of Africa, has long been recognized for its wealth of natural resources, endemic species, and high biodiversity. While Ethiopians have recognized the commercial value of their natural assets for some time, these assets remained largely unprotected until the mid-1960s, when the government instituted a conservation and protected area program. The primary intention of this program was to establish bylaws and areas for the conservation and protection of a range of species and habitats. The promotion of tourism and income generation was secondary priorities (WCMC, 1994; IUCN, 1992).

Even though Ethiopia is considered as one of the top 25 richest countries in the world in terms of biodiversity (WCMC, 1994) most of the ecosystems or habitats important for biodiversity conservation are not included in the country's system of protected areas. In Ethiopia, there are 9 national parks, 3 sanctuaries, 8 wildlife reserves and 18 controlled hunting areas covering an area of about 194,000 Km^2 or approximately 14% of the country's surface area (IUCN, 1992). However, except few, most of the protected areas are found only on paper. According to IUCN (1992), of the total protected areas, 30,316

km^2 (2.5%) only is actively managed. Up to now, no area has been formally protected in the country to conserve an ecosystem or habitat important for plant species although Ethiopia's biodiversity is mainly due to the high diversity of plant species (Tadesse Weldemariam, 2003).

The country's present faunistic potential consists of more than 272 terrestrial mammals, 862 bird species, 201 species of reptiles, 63 species of amphibians and 150 species of fishes. Among these, 31 mammal species, 17 bird species, 24 amphibian species, 9 reptile species and 4 species of fishes are believed to be endemic. The endemic bird species in Ethiopia is the highest in Africa (http://www.birdlife.org). Most of the endemic species of Ethiopian fauna are found in side the protected areas.

Babile Elephant Sanctuary is one of the largest protected areas in the country. This huge Sanctuary extends south from the small town of Babille in the direction of Fik. Five major rivers, the Gobele, Erer, Daketa, Borale and Fafen, flow southwards through the Sanctuary to drain into the Wabi Shebelle river (http://www.birdlife.org). The Babile Elephant Sanctuary which covers 6984 km^2 (Stephenson, 1976; Teshome Ashine, 1981; IUCN, 1990) was established in 1970, by Imperial order, to provide protection to wildlife, especially elephants and other large mammals. It is a home for different wild life species such as, elephant (*Loxodonta africana orleansi*), lion, fox, lesser kudu, spotted hyena, wild pig and baboon. In addition, it is an important bird's area of Ethiopia (http://www.birdlife.org).

2.5.1. Threats and challenges of protected areas

Environmental crises, like global warming, loss of biodiversity, desertification, pollution, etc. are becoming the major tribulations of human beings. Obviously, depletion of biodiversity is of utmost concern in the present global scenario. Unlike previous episodes of extinctions where natural phenomena were to blame, the current wave of desertification is driven by anthropogenic factors. Most of the threat to plants can be traced to man's need for food, both directly in searching for new land for his crops and indirectly through his animals. In many regions this leading not only to loss of species

and degradation of the vegetation cover over very extensive areas, but also to a loss of agriculture potential itself, both in the short and long term (IUCN, 1992).

Modification of ecosystem by human beings, mainly for agriculture, grazing and settlement, is considered to be the major threat to the conservation of Biodiversity (Chapin *et al.,* 2000), especially in developing countries (Swanson, 1999). Where this happening as in many of the ecological unstable areas of the dry land areas, it is arguable that the problem of how to avoid an ecological and human catastrophe is more intractable and more complex than ever before (IUCN, 1992). Desertification is one example: an increase in human population leads to inevitably over cutting of the few trees available for firewood and increased numbers of livestock lead to overgrazing which reduces the carrying capacity of the land. The pressure on the remaining grasses and unpalatable herbs also intensifies; the process is accentuated by any cycle of dry years, leading to permanent ecosystem damage. With the vegetation severely degraded, it would appear that the climate becomes increasingly arid and eventually only unproductive desert remains (IUCN, 1992).

In Ethiopia agricultural expansion is observed even in the protected areas. Therefore, agriculture forms the greatest threat to biodiversity conservation, since over 85% of the total population is engaged in agriculture (MEDAC, 1995). Agricultural production, which is the main stay of the population of Ethiopia, could not cope with the rapid population growth. Therefore, people scratch their living through extensive agriculture at the expense of forestlands. This may be due to the low production efficiency of the existing agricultural practices in the region.

Due to the ever increasing human and livestock population, the different vegetation types of the country are drastically dwindling both in physical and species composition. The loss of vegetation cover resulted in severe land degradation, environmental deterioration and shortage of plant resources.

The *Acacia* woodland was rapidly deteriorating all over the country due to expanding human and livestock populations, and also increasing demand for charcoal in cities and villages. The situation of the woodlands in the country, including Babile Elephant Sanctuary, is getting even worse today (Demel Teketay, 1995). They are subjected to severe destruction by cutting, burning, and overgrazing. If this trend continues, there is a great danger that they will either be degraded to a level difficult to regenerate or wiped out in few years' time (Demel Teketay, 1995). Even the current statistical data by Yirmed Demeke *et al.*, 2006, showed monthly on average 991.5 sacks of charcoal, 843 bundles of firewood and 800 bundles of house construction materials was recorded in the different part of the sanctuary. It is the biggest threat to the sanctuary and this implies that the wild animals living in them will have the same fate since they depend on these woodlands for food, shelter, and breeding. Hence, the threat is two-fold- the loss of vegetation and of animal diversity.

2.6. Ethnobotany and its importance

The term ethnobotany is a combination of two words, "ethno"- the study of people, and botany, the study of plants. Although the term has a long history, there has not been a single satisfactory interpretation for it. Hershberger defined ethnobotany as the study of the use of plants by aboriginal people (Harsgberger, 1896 cited in Cotton 1996). Twenty-one years later, Robbins and co-workers redefined ethnobotany to include not only how plants were used by indigenous people but also how they were perceived and understood within different cultures (Robbins *et al.*, cited in Cotton, 1996). Very recently, Martin (1995), defined ethnonotany as the study of local people's interaction with the natural environment, how they classify, manage and use plants that are available around them. So, ethnobotany is considered as the whole range of interactions of people with the plant world, including how indigenous people view in their own culture.

Ethnobotanical studies have played a role in revealing and promoting traditional practices that have been found useful in maintaining or enhancing biodiversity and sustainable use of biological resources (Godgil, *et al.*, 1993; Zemede Asfaw, 2004). Recording and

documenting the biocultural heritage of local people brings self-respect and self-esteem and more concern by the people for resources and indigenous knowledge.

In ethnobotanical study food, forage, medicinal plants are investigated. In addition, plants used for construction, furniture, fencing (dry and live), cultural value, and fuelwood are studied. Also plants of miscellaneous uses such as; laundry, cleansing, fragrances, aromatic, fumigation are documented. According to (Zemede Asfaw, 1997), many species of plants have multiple use value. So multiple use valued plant species are documented from Babile Elephant Sanctuary.

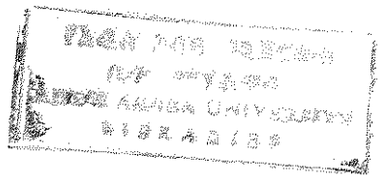
During food scarcity and famine, people rely heavily on wild food plants (Cotton, 1996; Zemede Asfaw, 1997). Wild food plants are very important sources of vitamins, trace minerals and other nutrients (Demissie, 1991, Tuxill, 1999). Non-cultivated food plants and wild relatives of cultivated plants play significant role in the improvement of crops. For example, cocoa, maize, wheat, cassava has also been improved with the help of genes from the wild (Hanneberge, 1992). Wild food plants also serve as a source of subsistence income from local marketing (Zemede Asfaw, 1997). These socio-economic benefits, for example genes, food values, income source obtained from a very wide range of useful wild food plants have brought significant due attention for the conservation of their habitat and associated indigenous knowledge.

According to Tesfaye Awas, 1997; Zemede Asfaw, 1997; Miruste Gidey, 1999, there is a wealth of indigenous knowledge of the use, management of plant resources among the local people of an area. However, unwise use and over exploitation can slowly eliminate a plant species from the environment (Peters, 1996). As a plant species is lost from a locality, the information contained in it will also be slowly blurred and finally become lost forever. Hence, so as to conserve both plants and information about the plants, pressure exerted by human on plant species should be well assessed.

Saving plant species and documenting and preserving indigenous knowledge are fundamental urgent issues to be accomplished (Cunningham, 1996). Studying the

relationship between people and plants, and the significance of plant use towards the well being of the community is extremely important (Martin, 1995; Cotton, 1996). As the local people and communities encounter cultural changes, unless documented and conserved, the knowledge of the people could vanish forever. This vital information is diminishing at an alarming rate. Hence, collecting and documenting it before it is lost forever is a fundamental urgent task (Maundu, 1995).

Ethnobotanical study is highly dependent on the effective use of anthropological, botanical, ecological, and linguistic methods. These methods were effectively used in the ethnobotanical study of the Babile Elephant Sanctuary. These methods employ the four basic data collection techniques; Interviewing, observation, Guided field walk and simulation (Martin, 1995). In this ethnobotanical study interview, observation and guided field walk are used. There are several analytical tools, which are used in the quantification and data verification (Martin, 1995; Cotton, 1996). Some of these are free listing, preference ranking, and direct matrix ranking, relative use value, paired and triadic comparisons (Martin, 1995; Cotton, 1996).



3. Study area

3.1. Study site

The study area is located in the Babile district which lies between $8^0$9' and $9^0$23'N latitude and $42^0$9' and $42^0$55'E longitude in the East Hararge semi-arid region. Babile Elephant Sanctuary (BES) lies between Harar city and Jijiga town, about 560 km from Addis Ababa. The elevation of the study area ranges from 850 m up to 1750 m a.s.l. (Fig. 1b). When the sanctuary was established in 1970 it covers about 6984 km^2 area (Stephenson, 1976, Teshome Ashine, 1980; IUCN, 1990) between the Eastern Hararge high mountain i.e. Mt. Gara Muleta to the west, and the Ogaden desert to the south-east. Even if the largest part of the sanctuary is found in the Babile district, some part is also found in the Fedis district. Four major rivers, the Fafem, Daketa, Erer and Gobelle flows southwards through the sanctuary into the Wabi Shebelle river (Fig. 1a). These rivers have length of 46 kms, 152 kms, 95 kms, and 92 kms respectively. The valley formed by the Daketa, Erer and Gobelle Rivers are the major features with in the sanctuary (http://www.birdlife.org). Out of these three valleys, the floristic composition of the Daketa valley was done by Demel Teketay (1995).

The largest and currently the basic vegetation cover in the sanctuary is that of the Erer valley, where this study was conducted. The Erer valley lies about 25 kms SE of Harar town. The area is a semi-desert plain at around 1350 m a.s.l. surrounded by a chain of rocky hills (EHPEDO, 2004). The total area of the valley is estimated to be 1500-2000 km^2. The Erer valley includes Erer 'Guda' and Erer 'Tika' valleys. The Erer 'Guda' and Erer 'Tika' valleys have permanent water at their junction. From this point water is flowing for approximately 20 kms to the south down the Erer valley and join Gobelle river about 50-60 kms southward (Stephenson, 1976). The Gobelle valley is part of BES, which is located in Fedis district. This valley is the last boundary of BES to the west. To the west of this valley, there is the highest mountain of East Hararge, i.e. Mt Gara Muleta with an altitude of 3400 m.

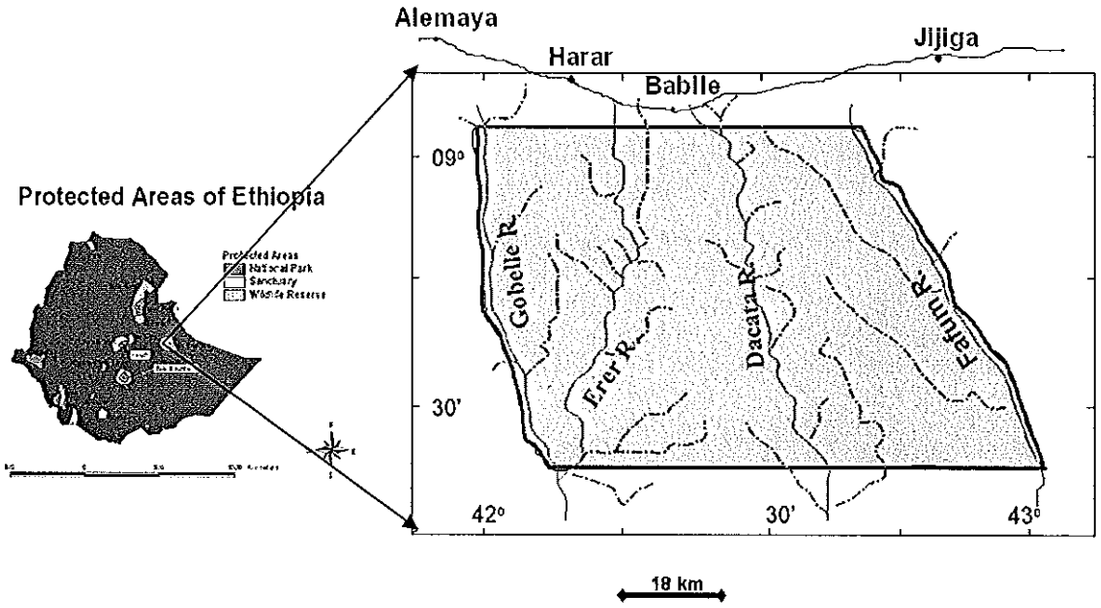


Fig. 1a. Map of the Babile Elephant Sanctuary (rivers & near by towns)

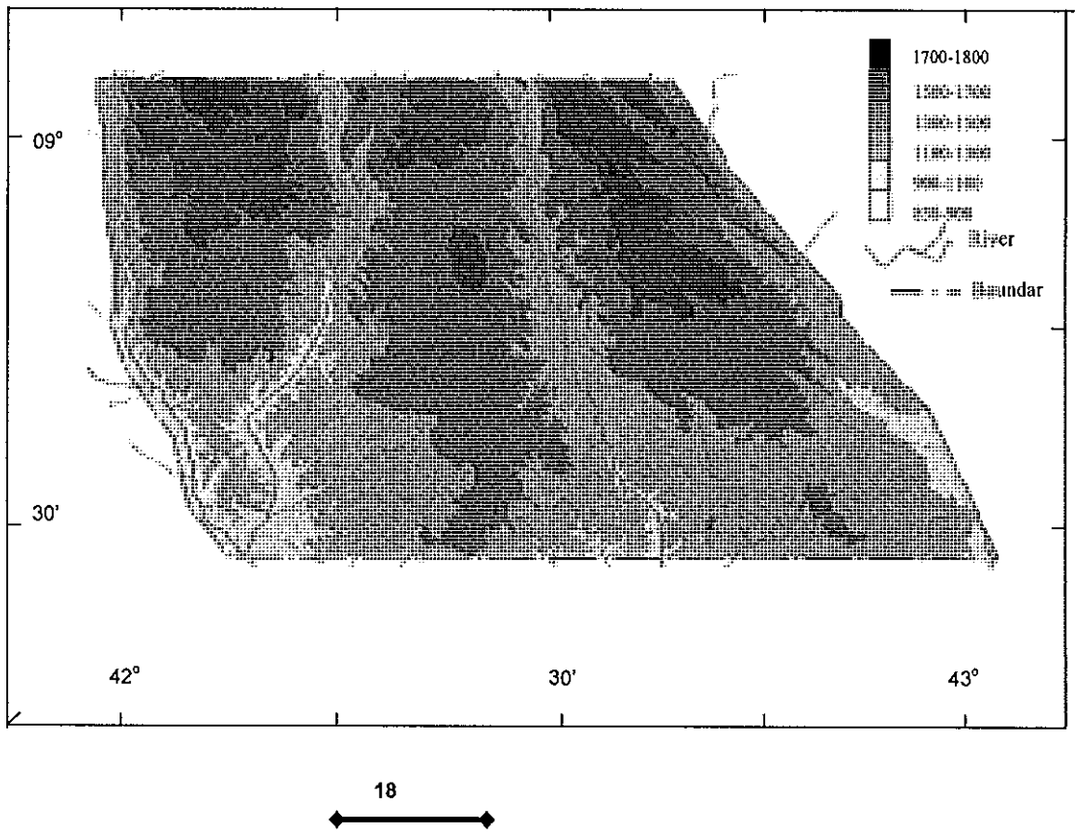


Fig. 1b. Altitudinal variation in the Babile Elephant Sanctuary.

3.2. Geology and Soil

The present land configuration and the distribution of rock and other natural phenomena in east Hararge administrative zone are the results of past geological history. In general, the geological formation of the zone can be categorized in to Precambrian rock, Mesozoic rock and Cenozoic rock (EHPEDO, 2004). Particularly the study area is characterized by Mesozoic rock. Some 225 million years ago, during the Mesozoic era, the Afro-arabian land was subjected to crystal movement which caused gradual subsidence of the land. This was followed by sea transgression (Indian sea) in the north-west direction. With the advance of the sea over the land, sandstone was deposited (Adigrat sandstone). The Adigrat sandstone is found in Babile district (*EHPEDO, 2004)*. Most of the area in the BES comprises sandstone with limestone in places, at around Fik (http://www.birdlife.org).

The physical and chemical compositions of soils are very important in determining the occurance, growth, diversity and distribution of plant species of the area. Accordng to OPEDB (2000) the major soil types of Babile are Regosols and regosols-arenosols association, lithosol, rendzinas and rankers association, alfisols/luvisols/nitosol/ acrisol and their association, and fluvisols and its association, cambisols and its association, vertisols and vertic fluvisols.

3.3. Climate

Rainfall and temperature are the major environmental factors that play significant role in the growth and distribution of plants. According to the Ethiopian agro-ecological division Babile district is classified in to 'woinadega' and 'kola' agro-climatic zones, covering 15% and 85% of the total area of the district respectively. The 'kola' agro-climatic zone consist arid and semi-arid climatic conditions. The BES is generally characterized by semi-arid climatic condition. The mean annual temperature is about 19.6^0C, ranging from a mean minimum of 11.9^0C to mean maximum of 27.2^0C. There is only a slight difference in temperature throughout the year, with the hottest months in April to June (maximum 29^0C) and the coldest months during October to December (minimum

Fig. 3. Bushland and thicket

Fig. 4. Riverine vegetation

Stephenson (1976) described the natural vegetation in the BES roughly in to two categories based on observation.

i. *Acacia* woodland. This vegetation occurs in ribbon strips along the valley floors. The density depends on soil richness and the amount of moisture or ground water available. The main tree species occurring are *A. tortilis, and A. seyal*. This forest is mainly dense in the Erer valley. *Boswellia neglecta (*Fig. 5*)* and *Commiphora* seems less dominant.

Fig.5. Species of *Boswellia neglecta* in the study are

This type of wood land becomes sparser and poorer in composition southwards to the sanctuary. Species of *Opuntia ficus-indica* became dominant in the *Acacia* wood land (Fig. 6).

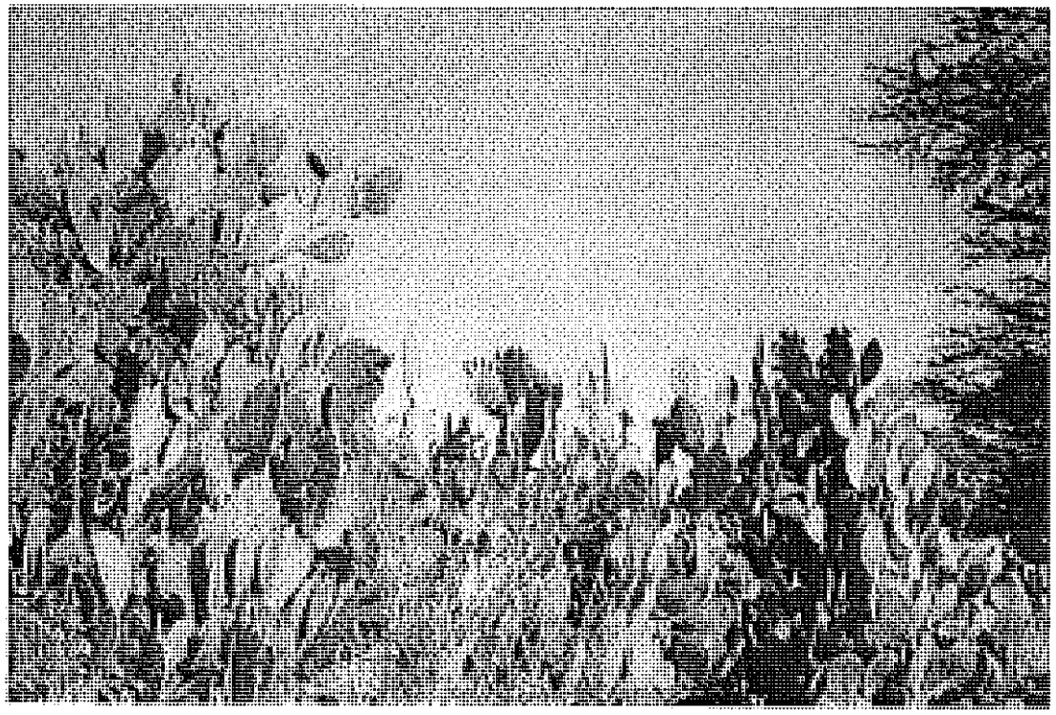


Fig. 6. ***Opuntia ficus-indica***

ii. Bush land. It takes over from the *Acacia* woodland at roughly where the hills flare out in to valley floors. It covers the hillsides and ridges excepting as detained above in the southern section between the Erer and Daketa valleys. *Acacia senegal is* dominant on poorer soils and *Acacia mellifera* on the better soils.

3.5. Wildlife

The sanctuary is a home for different wildlife species such as, elephant (*Loxodonta africana orleansi*), lion, fox, lesser kudu, greater kudu, leopard, spotted hyena, wild pig, salt's dik-dik, serval, wart dog, Hamadryas baboon and variety of reptiles and birds (Teshome Ashine, 1981).

3.6. Relief and topography

Geographically, the Babile district predominantly characterized by plains mainly Mulu bota, Adada bota from North to South direction along the rural gravel road from Babile to Fik town (In the Somali national regional state). There are also isolated hills in this plains

such as Kora (1518 m a.s.l.), Kurfa Ddenbe and plateaus as well as mountains such as Mt. Ambelber (1780 m a.s.l.) and Mt. Sarbadin to the North and North eastern parts of the district. Altitudinaly the district stretches between 950 and 2000 m a.s.l. the lowest place lies in the Daketa valley in the BES.

About 94.4% of the total area of the district is characterized by plains and isolated hills, 4.6% are dissected plateaus and mountains and 1% is rift valley including gorges. The Gobelle valley which skirts the western flank of Mt. Gara Muleta has the lowest elevation of 600 m a.s.l. would be better described as a gorge (Stephenson, 1976). A broad densely cultivated ridge or plateau lies between Gobele valley and the Erer guda which becomes similarly gorgelike in its mid-reaches after being jointed by Erer tika. There is also a permanent swamp some 10 kms up the Erer Guda.

The Daketa valley, also known as the 'rocky valley' (Demel Teketay, 1995) is less deep and more gentel-sided. This dry and rocky valley is unsuitable for agriculture except as a range for livestock (Demel Teketay, 1995) and home for wildelife. The Fafem valley has generally, a broader floor than the Daketa valley and has hillsides to the east such as Karamara.

3.7. Population and Land use

Total area of east Hararge zone covers an area of 22622.6 km^2. According to the 1994 population and housing census report, the total population of east Hararge zone was 2,054,596 with annual growth rate of 2.23% for the rural and 4.1% for the urban areas. After some 6 years the total population of the zone was estimated 2,202,248 where male 1,122,878 and female 1,079,370 (EHPEDO, 2001).

The population of the zone is unevenly distributed. This unevenness of population distribution is primarily the result of the differences in the suitability of a given area for settlement and secondly the result of socio-economic and historical factors.

The terrain characteristics (relief), climate, soil fertility, water, disease prevalence both for human and livestock are the major environmental factors that influence population distribution. The non-environmental factors that contribute to the variation of population distribution are accessibility of road network, social infrastructure such as schools, health centers, and potable water.

The Babile district like other 'kola' district of the zone (Gola Oda, Kurfa Chele and Fedis) supports the lowest proportion of zonal population. It accounts about 2.8% of the total population of the zone (EHPEDO, 2001). Based on 1994 Population and Housing Census crude population density of the district has grown 18 person/km^2 in the year 1990 to 26 persons/ km^2 in 1995. The average house holding sizes for rural and urban areas of the district were 4.7 and 4.0 respectively.

The population size between 1990 and 1995 showed an increment by 26541 or 47.8% (Table 1). Obviously, this population increase leads to an increment for the demand of natural resources, such as arable land, water, wood for construction and energy (firewood and charcoal). It might be this population increment in the last ten or more years that could lead high human settlement in the Babile Elephant Sanctuary.

Table 1. Population size of Babile district

Year	Area	Population			Area km^2	Density (person/km^2)
		Male	Female	Total		
1990	Rural	22785	21985	44767		
	Urban	5334	5450	10784		
	Total	28118	27435	55553	3169.06	18.9
	Percent	50.6	49.4	100		
1995	Rural	35462	34214	69676		
	Urban	6088	6330	12418		
	Total	41550	40544	82094	3169.06	26
	Percent	50.6	49.4	100		

(Source- EHPEDO, 2004)

The majority of the population depends on crop production under taken by rainfed agriculture and irrigation in some places. The cereal crops produced in the district are sorghum, maize; pulses and oil seeds are haricot bean, "selit" and ground nut. Chat is the major cash crop in the district. Fruits and vegetables such as sweet potato, tomato, pepper, papaya, guava, and mango are the major ones produced in the district (Table 2).

Table 2. Major crops growing in the Babile district.

Crop category	Scientific name	Common name	Local name
Ccreals	*Sorghum bicolor* L.	Sorghum	Bishingaa
	Zea mays L.	Maize	Bekollo
Pulses	*Phaseolus vulgaris* L.	Haricot beans	Dangulle
	Pisum sativum L.	Peas	Atera
Oil crops	*Arachis hypogea*	Ground nut	Lozii
	Sesamum indicum	Sesame	Selixaa
Fruits and vegetables	*Lycopersicon esculentum* Mill.	Tomato	Timatima
	Carica papaya L.	Papaya	
	Ipomoea batata (L.) Lam.	Sweet potato	
	Capsicum frutescens L.	Pepper	Berberri
	Psidium guajava L.	Guava	Zeytun
	Mangifera indica	Mango	
Cash crops	*Catha edulis* (Vahl) Forssk.		Jimaa
	Saccharum officinarum L.	Sugar cane	Alaa

(Source- EHPEDO, 2004)

Livestock rearing is also the major activity of the population in the study area (Table 3).

Table 3. Two years data of livestock population in Babile district.

Types of livestock	Number	
	2001/2	2002/3
Cattle	39524	39844
Goats	22403	22456
Sheep	4573	4607
Donkey	5322	5343
Camel	11288	11352
Poultry	12854	12955

(Source- EHPEDO, 2004)

The land use pattern of the Babile district was categorized in to seven types (Table 4).

Table 4. Land use pattern of Babila district over the year 1998-2002.

Land use	1998-2002	
	Area (ha)	**Percent (%)**
Cultivated land	17113	5.4
Cultivable land	6022	1.9
Pasture/ grazing land	6655	2.1
Forest and wood land	4437	1.4
Bush and shrub	65916	20.8
Rocky, waste and degraded land	207257	65.4
Land use for social purpose	9507	3
Total area	316907	100

(Source- EHPEDO, 2004)

4. Materials and methods

4.1. Data collection methods

4.1.1. Vegetation data

A reconnaissance survey was carried out from 5-10 September 2005, in order to have an impression of the site condition and to determine the sampling method to be used for vegetation data collection. Since the study area has different formation types, stratified sampling design, as described by Krebs (1989) was used to collect data on vegetation. Twelve representative sites were selected by visual observation on the bases of homogeneity in floristic composition, and each site was sampled systematically. Among the selected sites, 5 were in the woodlands, 4 in the bushlands, and 3 in the riverine forest. Vegetation data collection was carried out from September to October, 2005 and April 2006 after the long and short rain seasons respectively.

A total of 75 sample plots were established in the different vegetation type. The size of the major plot for tree species was 20 m x 20 m, as recommended by Kent and Coker (1992). In each sample plot, all tree species with diameter at breast height (DBH) $\geq$ 2.5 cm and height $\geq$ 1.5 m were recorded. With in the major plot of 400 m^2, five sub-plots of each 5 m x 5 m (25 m^2) were set up. These plots were used to collect vegetation data of shrubs and climbers with diameter at stump height (DSH) $\geq$ 1.5 cm and height $\geq$ 0.5 m and the mean of these five subplots were used in the analysis.

Germinants, seedlings and saplings were recorded for analysis of regeneration status of trees within each 25 m^2 sub-plots. All individuals below a height of 0.1 m were considered as germinants, and only height measurement was taken. Individuals with a height between 0.1 and 1.5 m were considered seedlings, and both height and diameter measurements were taken (DBH< 2.5 cm and height < 1.5 m). Individuals with DBH < 2.5 cm and height >1.5 m were considered as sapling.

Within each 25 m^2 sub-plots, five 1 m x 1 m sub-plot was used to collect data on the species diversity and richness of herb and grass species and data on germinants (below a height of 0.1 m) and seedlings (between 0.1 and 0.5 m) of shrubs and climbers.

Plant communities were classified using species composition and their percent cover which was estimated as a vertical projection onto the ground of all aboveground parts of the individual plant species expressed as percentage of the corresponding plot area following Mueller-Dombois and Ellenberg (1974) and later converted into a modified 1-9 Braun-Blanquet scale (Van der Maarel, 1979) as follows:

1= rare, generally one individual

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

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

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

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

6= 12.5-25% cover of the total area.

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

8= 50-75% cover of the total area.

9= >75% cover of the total area.

The extent of external pressure on the sanctuary was assessed following a 5 point arbitrary scale of disturbance with a particular focus on agricultural encroachment, human settlement, logging, firewood and charcoal making, livestock browsing, fire, and honey production. where 5 is for highest treat, 4 for high, 3 for moderate, 2 for less and 1 for the least treat in the Babile Elephant Sanctuary.

Plant species were recorded and voucher specimens of plant species that had fruits and flowers were collected, pressed, dried, identified and deposited at the National Herbarium of Ethiopia (ETH), Addis Ababa University. The nomenclature of plant names in this study follows the published volumes of flora of Ethiopia and Eritrea (Hedberg & Edwards, 1989, 1995; Edwards *et al.*, 1995, 1997, 2000), and by comparing with authentic specimens at the national herbarium (ETH), Addis Ababa University.

The DBH (Diameter at Breast Height i.e., 1.3 m from the ground) and DSH (Diameter at Stump Height i.e. 0.3m from the ground) were measured over bark using diameter tape. The height of all trees and shrubs were measured by suunto clinometer and estimations were made when ever difficult to measure. Geographic location and slope of each major sample plots were also determined. Geographic location of each plot at the center was determined using Garmin GPS 48.

4.1.2. Ethnobotanical data

Participatory rural appraisal (PRA) technique was employed to collect ethnobotanical data, as recommended by Martin (1995). Six sampling sites (1 camp and 5 villages) were identified from the study area where settled farmers and trans-human pastoralists are found. The names of the selected camp and villages (Genda) are Menschen for Menschen (MfM) camp, Gende Abdi, Genge Negeya, Kurfa Guratti, Raree Adem and Wolbi. Basic information on the use of plant species including their local names, uses, parts used and method of preparation were collected. Information was collected from 40 informants (38 male and 2 female) and field observation was conducted. Out of 40 informants 15 (all men) are key informants selected with the assistance of clan leaders, peasant association leaders and local communities. Some numbers of households from each village were taken randomly and appropriate number of informants was selected. The selection of key informant was using systematic sampling and other informants by random sampling method. Both age and gender were considered in the informant sampling. The informants were grouped into three age group i.e., 14-20, 24-40 and above 40.

Semi-structured questionnaires and interview was administered in the local languages (Oromoo and Somali language). Most of the interview was made in the field in order to avoid the risk of confusing identity of plant species. Photographs, video camera and tape recorder were used to document information from the informants.

For gathering information on the woody species browsed by elephants in addition to local communities selected for ethnobotanical information, the sanctuary scouts who have served for more than five years in the BES were involved. Five sanctuary scouts were participated. In addition, field observation while elephants are browsing have been conducted.

After identification of the most important 10 plant species, based on their values as perceived by the informants, food, forage, medicinal, construction & craft, fuel (Fire wood & charcoal) and market value plants, preference ranking were employed as described by Martin (1995) and Cotton (1996). For the preference ranking a ten point rating scale as perceived by the informant were used.

Moreover, local plant names and their uses were asked for and recorded at different sites in different periods with the same and different informants so as to confirm the validity and reliability of the recorded information.

4.2. Data analysis

4.2.1. Vegetation data analysis

Data for each species which were originally estimated and recorded in the form of percent cover value were converted into cover-abundance value of modified Braun Blanquet scale (Van der Maarel, 1979). A computer program called TWINSPAN (Two Way INdicator SPecies Analysis) program of the Community Analysis Package (CAP) version 2.0, as recommended by Pisces (2003) was used for analysis of communities. TWINSPAN is one of the most popular classification programs in community ecology and its basic idea is that samples can be characterized by "differential species" that are prevalent on one side of a dichotomy (Hill *et al.*, 1975; Hill, 1994). In TWINSPAN, plots are categorized based on similarities or dissimilarities in species composition.

Shannon-Weiner Diversity Index was analyzed using Biodiversity professional soft ware program version 2 (Niel, 1997) using the following formula:

$$H' = - \sum_{i=1} pi \ln (pi)$$

Whereby: H = Shannon-Wiener Diversity Index

Σ = Summation symbol

pi =the proportion of individuals found in the i^{th} species.

ln = log base$_e$

The Shannon index is often preferred over others because the species abundances are standardized to proportions (Kent & Coker, 1992). The value of Shannon diversity index is usually found to fall between 1.5 and 3.5 and only rarely surpasses 4.5 (Kent & Coker, 1992).

Species richness is a biologically appropriate measure of alpha diversity and is usually expressed as number of species per sample area (Whittaker, 1972).

Species evenness measures the equity of species in a given sample area. Equitability (evenness) was calculated using Biodiversity professional soft ware program version 2 (Niel, 1997) from the ratio of observed diversity to maximum diversity using the equation:

$$E = H'/H_{Max} = H'/\ln(S)$$

Whereby: E = Evenness

H' = Shannon-Wiener Diversity Index

H_{Max} is the maximum level of diversity possible with in a given population, which equals ln(number of species).

S = total number of species in the sample

E is normal between 0 and 1, and with 1 representing a situation in which all species are equally abundant.

Basal area is the cross-sectional area of tree stems at diameter at breast height. Generally it is a measure of dominance where the term "dominance" refers to the

degree of coverage of a species as an expression of the space it occupies (Lamprecht, 1989), and calculated by using the following formula.

$$BA=\Pi d^2/4$$

Where BA = Basal area in m^2 per hectare

d= diameter at breast height

Π= 3.14

Importance Value Indice (IVI) was analyzed for woody species.

Importance Value Index (IVI) of a species was calculated from the sum of relative dominance, relative density and relative frequency as recommended by Kent and Coker (1992). Relative dominance (RD) is the total basal area of a species/ total basal area of all species x 100; relative density (Rd) is the total number of individuals of a species / total number of individuals' x 100; and the relative frequency (Rf) is the frequency of species/ sum frequencies of all species x 100.

$$IVI_i = \left[\frac{BA_i}{\sum BA_j} x100\right] + \left[\frac{N_i}{\sum N_j} x100\right] + \left[\frac{f_i}{\sum f_j} x\ 100\right]$$

Where: IVI_i = the Importance Value Index of the i^{th} species.

N_i = the number of individuals of the i^{th} species; N_j = the sum of individual of all woody species.

BA_i = the basal area of the i^{th} species; BA_j = the total basa area of all woody species.

F_i = the absolute frequency of the i^{th} species; f_j = the total sum of the absolute frequency of all woody species.

Similarity coefficient of community types was assessed in terms of species composition using Sorensen's similarity index (Kent and Coker, 1992). Generally, Sorensen's coefficient is preferred over others because it gives weight to the species that are common to the quadrats or samples (in these case communities) rather than to those that only occur in either sample.

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

Where 'c' is the number of species common to both community types, 'a' is the number of species present in one of the community to be compared, and 'b'is the number of species present in the other community.

4.2.2. Ethnobotanical data analysis

Ethnobotanical data were analyzed using both qualitative and quantitative methods (Martin, 1995: Cotton, 1996). SPSS computer program was used. Simple preference ranking is used. In this analysis method, each informant is involved to think of some items (in this case 7 & 5) and rank them based on a given criterion, according to their personal preference or perceived degree of importance in the community. The most important or preferred items are assigned with the highest number (in this case 7 is the highest for food & 5 for human medicinal plants), while the least preferred or important item is given the lowest number which is "1".

Direct matrix ranking was also used for identification of major plants used by the local community. Direct matrix ranking involves asking an informant to order given items according to several criteria or attributes, one at a time. For each attribute, the most preferred item is assigned with the highest number, depending on the number of items being compared (in this case 10 items), and the least preferred one with the least number, which is "1" (Martin, 1995: Cotton, 1996). Then the informants were asked to rate their preferences and the overall number of an item chosen by each informant was added to give the preference rank of the given item (Martin, 1995: Cotton, 1996).

In addition, population structure, density and regeneration status of multi-purpose woody species was analyzed using SPSS program.

5. Results

5.1. Floristic Composition

A total of 237 plant species in 155 genera and 57 families were identified from the study area. The complete list of species is given in Appendix 1. Out of the total species Fabaceae had 36 (15.1%) species, Poaceae had 19 (8.0%) species, Asteraceae had 15 (6.3%) species, Acanthaceae had 14 (5.9%) species, Tiliaceae had 12 (5.0%) species, Euphorbiaceae had 10 (4.2%) species, Malvaceae had 10 (4.2%) species, Lamiaceae had 10 (4.2%) species, Convolvulaceae had 9 (3.8%) species, Asclepiadaceae had 8 (3.4%) species; Amaranthaceae, Boraginaceae, and Capparidaceae each has 6 species (each 2.5%); Rubiaceae, Sapindaceae and Solanaceae has each 4 species (each 1.7%); Burseraceae, Anacardiaceae, Sterculiaceae and Verbenaceae has each 3 species (each 1.3%), 17 families have 2 species each (account 14.3%) and 22 families are represented by only 1 species each (account 9.2%) (Appendix 2).

The ten species-rich families contribute 60.1 % of the total plant species, and the rest 47 families contribute 39.9% of the total plant species.

Out of the total plant species 102 (42.9%) are herbs, 58 (24.8%) are shrubs, 32 (13.4%) are trees, 20(8.4%) are grasses, 17 (7.1%) are climbers, 5(2.1%) are shrub/trees, 2 (0.8%) are ferns, 1 (0.4%) is epiphyte (Fig. 7).

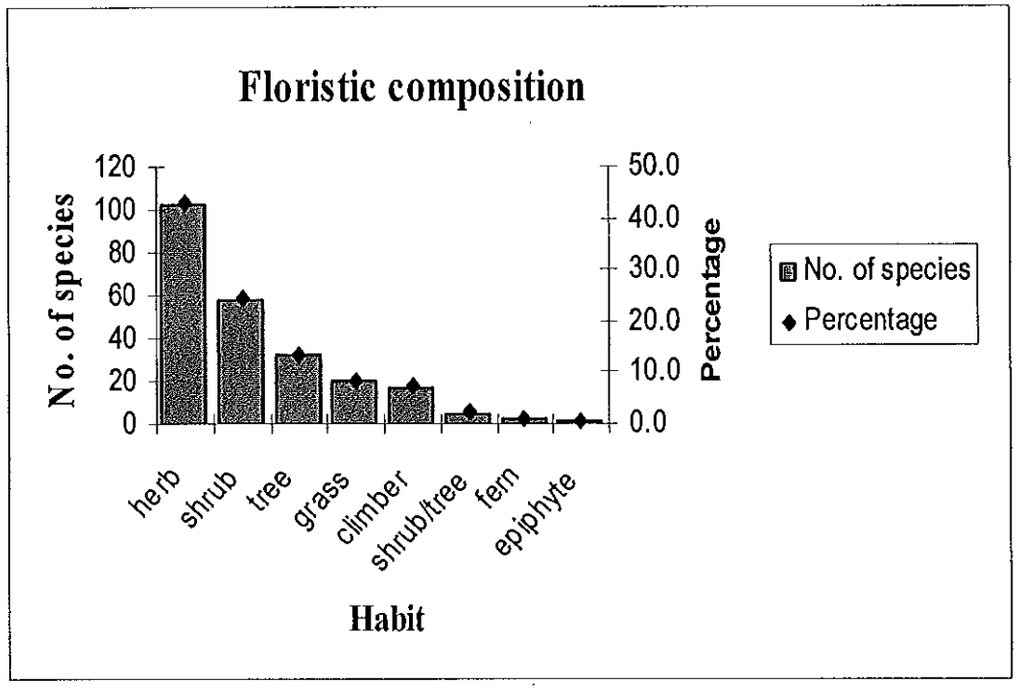


Fig. 7. Floristic composition of the Study area

5.2. Plant Community Types

In this study, the term "plant community" is simply used in the sense of describing a group of the individuals of different plant species occupying the area under study. Six plant communities were identified from the 75 plots analyzed. The six communities obtained in this analysis were named after one or two of the dominant species and/or characteristic species, which occur in each group using the relative magnitude of mean cover abundance, defined as the mean cover abundance value of a species in different quadrats that occurs in a given community (Table 5). The basic feature of each community is summarized as follows:

Community 1. *Tamarindus indica* community type. This community is in the riverine forest of lower Erer River. The altitudinal range of this community is between 1150-1260 m a.s.l. and the slope angle is less than 5%. An indicator tree species with a significant cover value is *Tamarindus indica.* The tree species are *Balanites aegyptiaca, Acacia robusta*, *Oncoba spinosa*, and *Opuntia ficus indica*. The shrub species are *Acacia brevispica* and *Capparis tomentosa.* Climbing species of this community is chiefly

Pentarrhinum somalensis. The field layer is characterized by *Achyranthes aspera, Plumbago zeylanica, Solanum nigrum, Abutilon bidentatum, Commelina stephaniniana,* and *Panicum monticolum.* Expansion of agriculture was observed with in this community. The surface feature is mainly loam soil.

Community 2. ***Acacia robusta-Acokanthera schimperi*** **community type.** This community is in the riverine forest of upper Erer River. The altitudinal range is between 1200 and 1250 m a.s.l. and the slope angle is less than 5%. The dominant tree species with significant mean cover abundance value is *Acacia robusta* and *Acokanthera schimperi*. Abundant shrub species are, *Senna singueana* and *Solanum incanum*. An exotic species, *Lantana camara*, is the most serious threat observed in this community. *Commicarpus sinuatus* is the common climber. Understorey layer of this community is occupied by *Abutilon bidentatum, Hibiscus dogolensis, Justicia diclipteroides, Hibiscus micrantus,* and *Setaria verticillata.* High expansion of agriculture was observed along this community. The surface feature is loam soil.

Community 3. ***Acacia seyal -Balanites aegyptiaca*** **community type.** This community is in the *Acacia* woodland. The altitudinal range of this community is between 1200 and 1330 m a.s.l. and the slope angle is less than 15%. The dominant tree species with significant cover value are *Acacia tortilis* and *Balanites aegyptica.* The common tree species are *Acacia seyal* and *Acacia nilotica.* Less abundant trees are *Acacia albida* and *Balanites glabra.* The shrub species of the community include *Acacia oerfota, Capparis sepiaria, Carissa spinerum, Euphorbia burgeri, Chionothrix latifolia, Acalypha fruticosa* and *Barleria eranthemoides*. The field layer is mainly characterized *by Blepharis maderaspatensis, Dichrostachys cinerea, digitaris ternate, Indigofera parviflora, Ipomea obscura, Ocimum forskolei, Eragrostis aspera,* and *Eragrostis papposa. Periploca linearifolia* is the common climber in this community. The surface feature is mainly sandy.

Community 4. ***Acacia senegal-Acalypha fruticosa*** **community type.** This community is in *Acacia* deciduous bushland and thicket and scattered bushland. The altitudinal range is

Table 5. Synoptic table to identify indicator species having high mean cover abundance value (Bold numbers in the table represents the mean cover abundance value of dominant species in each community).

Scientif name	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
Community size*	**5**	**10**	**21**	**19**	**10**	**10**
Tamarindus indica	**5.4**	0.0	0.0	0.0	0.0	0.0
Capparis tomentosa	3.6	0.0	0.8	1.3	0.0	0.0
Oncoba spinosa	4.0	0.0	0.0	0.0	0.0	0.0
Panicum monticolum	2.8	3.0	0.0	0.0	0.0	0.0
Acacia robusta	3.0	**8.7**	0.0	0.0	0.0	0.0
Acokanthera schimperi	0.0	**4.6**	0.5	0.0	0.0	0.0
Solanum incanum	0.0	2.4	0.0	0.8	0.0	0.0
Balanites aegyptiaca	2.2	0.3	**5.6**	0.4	0.0	0.5
Acacia tortilis	0.0	0.0	4.9	0.8	4.1	1.9
Acacia seyal	0.0	0.0	**3.6**	0.0	0.0	0.0
Ipomea obscura	0.0	0.0	2.4	0.7	1.2	0.9
Acalypha fruticosa	1.4	2.0	2.1	**6.8**	1.5	1.8
Acacia senegal	0.0	2.1	2.2	**6.7**	2.2	1.8
Acacia mellifera	0.0	1.6	3.5	5.4	4.3	2.7
Grewia bicolor	0.0	0.0	0.0	2.3	0.3	2.2
Terminalia brownii	0.0	0.0	0.0	0.0	**5.2**	2.5
Boswellia neglecta	0.0	0.0	0.0	0.0	**5.0**	1.8
Rhus natalensis	0.0	0.0	0.0	0.0	4.1	0.5
Crabbea volutina	0.0	0.0	0.0	0.0	3.4	0.5
Premna oligotricha	0.0	0.0	0.0	0.0	3.4	0.0
Berchemia discolor	0.0	0.0	1.1	0.0	2.8	1.5
Grewia schweinfurthii	0.0	0.0	0.0	0.0	3.2	0.0
Acacia bussei	0.0	0.0	1.8	0.6	1.8	**4.8**
Commiphora schimperi	0.0	0.0	0.0	0.0	2.2	**3.2**
Grewia tenax	0.0	0.0	0.0	1.7	2.2	**4.2**
Cenchrus ciliaris	0.0	0.0	0.0	0.9	0.6	2.8
Opuntia ficus-indica	3.4	3.6	2.2	2.3	3.5	1.2

* Number of quadrats grouped in each community type.

Community 6. *Acacia bussie-Grewia tenax* community type. This community is in the *Acacia–Commiphora* woodland. This community occurs at the altitudinal range between

4000 and 4740 feet a.s.l. having the slope angle of between 20-50%. The dominant trees and shrubs in this community are *Acacia bussie* and *Grewia tenax.* Less abundant trees and shrubs are *Commiphora schimperi, Balanites glabra, Grewia flavescens, Combretum molle, Acacia albida, Berchemia discolor, Acacia brevispica, Acacia mellifera. Terminalia brownii, Grewia ferruginea* and *Grewia erythrea.* Climbers are *Capparis fascicilaris, Cissus rotundifolia,* and *Jasminum eminii.* The field layer is composed of *Blepharis edulis, Cenchrus ciliaris, Chloris pycnothrix, Corchorus tridens, Leucas martinicensis, Melinis repens, Ocimum gratissimum, Plectranthus rupestris* and *Enteropogon macrostachyus. Actiniopteris dimorpha* and *Adiantum capillus-veneris* are ferns in this community. The surface feature is mainly rocky.

5.3. Floristic diversity

The overall plant diversity (Shannon Diversity index) and evenness in the Erer Valley is 3.55 and 0.72 respectively.

Species richness ranged from 31 up to 79 where the least was from community 2 and highest from community 3. Community 2 has the least species evenness value (0.59) where as community 5 the highest (0.83).The Shannon-Weiner index ranged from 2.10 up to 3.44 where the least was for community 2 and highest for community 3. In general, Communities 3, 4, 5 and 6 have high species diversity and richness while communities 1 and 2 have low diversity and richness (Table 6).

Table 6. Species richness, evenness and diversity in the six plant community types.

Communities	Richness (N)	Evenness (E)	Diversity (H')	H'Max
1	31	0.70	2.44	3.43
2	34	0.59	2.10	3.52
3	79	0.78	3.44	4.36
4	71	0.72	3.10	4.26
5	59	0.83	3.39	4.10
6	58	0.80	3.25	4.00

The three formation types stratified for sampling purpose shows differences in species richness, evenness and diversity (Table 7). The woodland shows the highest diversity and richness followed by bushland and thicket. The riverine forest shows the least diversity and richness. Even if the woodland shows the highest diversity and richness, it is the second in terms of evenness.

Table 7. Diversity, richness, and evenness of plant species in the three formation types.

parameters	Riverine	Woodland	Bushland and thicket
Diversity (H')	2.23	3.24	3.10
Richness (N)	36	110	71
Evenness (E)	0.62	0.68	0.72
H'max	3.58	4.7	4.26

5.4. Floristic similarity

Results from Sorensen's similarity coefficient analysis indicates that communities 1 and 2 (58%), 3 and 4 (57%), & 5 and 6 (54%) have high similarity of species composition or more number of common species between them (Table 8).

Table 8. Sorensen's similarity coefficient in species composition between the six community types.

Communities	1	2	3	4	5	6
1	-					
2	0.58	-				
3	0.30	0.32	-			
4	0.29	0.31	0.57	-		
5	0.15	0.23	0.43	0.42	-	
6	0.18	0.25	0.41	0.40	0.54	-

Less similarity was obtained between community 1 & 5 (15%), 1 & 6 (18%), 2 & 5 (23%), 2 & 6 (25%), and 1& 4 (29%). There is a significance difference ($P < 0.05$) between high similarity communities and less similarity communities grouped above.

5.5. Woody species density

The total density of woody species is 19991 individuals ha^{-1}, where the total density of trees is 394 individuals ha^{-1} (2.7% of the total density), shrubs 17460 individuals ha^{-1} (86.3%) and climbers 2137 individuals ha^{-1} (11%). The densities of six species: *Opuntia stricta* (26.5%), *Acacia senegal* (9.77%), *A. brevispica* (8.76%), *Euphorbia burgeri* (6.44%), *Acacia mellifera* (4.94%), and *Grewia tenax* (4.19%) constitute about 60.6% of the total density of woody species. The rest 61 species constitute 39.4% of the total density. The mean density of trees, shrubs and climbers was enumerated (Table 9).

Table 9. The mean density of trees, shrubs and climbers in the study area.

Habit	Mean ± S.E. individuals ha^{-1}	Minimum individuals ha^{-1}	Maximum individuals ha^{-1}	Number of species
Trees	32 ± 9.96	3	167	22
Shrubs	619 ± 203.3	64	3843	36
Climbers	315 ± 103.4	53	835	9
Total	385 ± 114.2	3	3843	67

In each community, density was calculated for woody species. Community 4 is the highest in terms of shrub density (14579 individuals ha^{-1}) and community 1 is the lowest density (1360 individuals ha^{-1}). Inversely community 4 is the lowest in terms of tree density (198 individuals ha^{-1}) and community 1 is the highest (550 individuals ha^{-1}). It was mentioned that community 4 is mainly from deciduous bushland and thicket where as community 1 is from riverine forest.

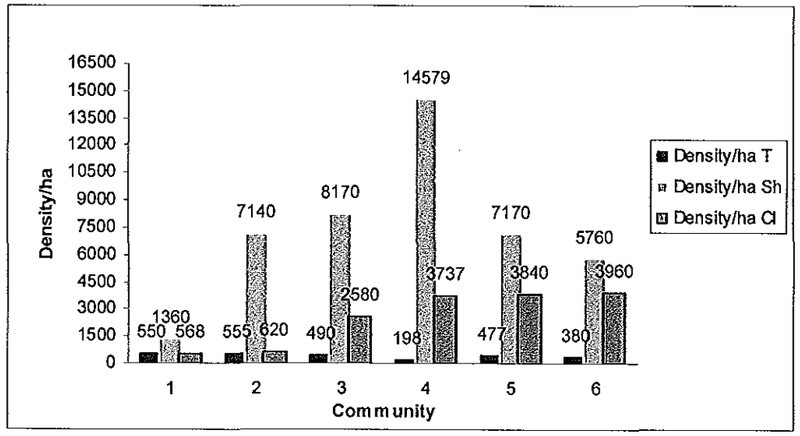


Fig. 8. Density ha^{-1} of trees, shrubs and climbers in the six community types. (T = tree, Sh = shrub, Cl = climbers)

The three formation types that were stratified for sampling purpose shows significant differences in density of individuals per hectare of trees, shrubs and climbers . Bushland and thicket is the highest in terms of shrubs (14574 individuals ha^{-1}) and climbers density (3737 individuals ha^{-1}) but the lowest in trees density (198 individuals ha^{-1}). Riverine forest is the highest in terms of trees density (553 individuals ha^{-1}) but the lowest in shrubs (5853 individuals ha^{-1}) and climbers density (565 individuals ha^{-1}) (Fig. 9).

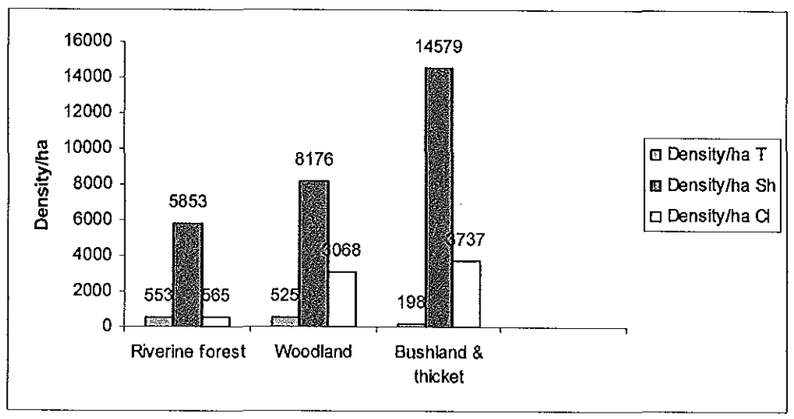


Fig. 9. Density per hectare of trees, shrubs and climbers in the three-formation types.

5.6. Basal area (BA) and Importance Value Indies (IVI) of woody species

The total basal area (m^2/ha) of the woody species in the study area is 17.8. The highest proportion of mean basal area was accounted to *Acacia robusta* (7.01m^2/ha) and followed by *Tamarindus indica* (2.46 m^2/ha), *Opuntia-ficus indica* (1.13 m^2/ha), *Acacia bussei* (0.92 m^2/ha), *Terminalia brownii* (0.76 m^2/ha), *Acacia tortilis* (0.7 m^2/ha), *Balanites glabra* (0.37 m^2/ha), *Acacia seyal* (0.34 m^2/ha), *Berchemia discolor* (0.27 m^2/ha), and *Balanites aegyptiaca* (0.26 m^2/ha) (Table 10). These 10 tree species account about 80% of the total basal area where their density is 566 individuals ha^{-1} or only 2.2% of the total density of woody species.

Trees and shrubs with IVI > 10 are *Acacia robusta, Opuntia stricta, Acacia senegal, Acacia brevispica, Tamarindus indica, Opuntia ficus-indica, Acacia mellifera* and *Euphorbia burgeri* (Table 10). Relatively high IVI values of these species indicate their ecological value or importance value in the study area. Most multipurpose woody species like, *Acacia tortilis, Acacia bussei, Balanites aegyptiaca, Berchemia discolor, Commiphora erythraea,* and *Acacia etbaica* resulted IVI < 10.

Table 10. Importance Value Indies (IVI) of some dominant woody species. (Habit; T = tree; Sh = shrub; Cl = climber; S/T = shrub/tree)

Scientif name	Habit	freq	Dens/ha	BA m^2/ha	Rfre	Rden	Rdom	IVI
Acacia robusta	T	15	100.7	7.006	1.300	0.39	39.3	41.0
Opuntia stricta	Sh	57	3842.7	0.963	4.939	26.50	5.4	36.8
Acacia senegal	Sh	52	2522.7	0.191	4.506	9.77	1.1	15.3
Acacia brevispica	Sh	59	2261.3	0.180	5.113	8.76	1.0	14.9
Tamarindus indica	T	5	15.7	2.462	0.433	0.06	13.8	14.3
Opuntia ficus-indica	T	50	216.7	1.130	4.333	0.84	6.3	11.5
Acacia mellifera	Sh	50	1274.7	0.260	4.333	4.94	1.5	10.7
Euphorbia burgeri	Sh	36	1664.0	0.191	3.120	6.44	1.1	10.6
Acacia bussei	T	40	47.3	0.917	3.466	0.18	5.2	8.8
Grewia tenax	Sh	35	1082.7	0.112	3.033	4.19	0.6	7.9
Acacia tortilis	T	36	41.3	0.702	3.120	0.16	3.9	7.2
Terminalia brownii	T	12	34.3	0.762	1.040	0.13	4.3	5.5
Balanites glabra	T	33	33.7	0.369	2.860	0.13	2.1	5.1

Grewia ferruginea	Sh	32	496.0	0.020	2.773	1.92	0.1	4.8
Grewia flavescens	Sh	32	384.0	0.008	2.773	1.49	0.0	4.3
Balanites aegyptiaca	T	28	31.0	0.262	2.426	0.12	1.5	4.0
Grewia bicolor	Sh	20	410.7	0.015	1.733	1.59	0.1	3.4
Capparis tomentosa	Sh	18	266.7	0.120	1.560	1.03	0.7	3.3
Berchemia discolor	T	17	15.3	0.268	1.473	0.06	1.5	3.0
Capparis fasicularis	Sh	13	293.3	0.120	1.127	1.14	0.7	2.9
Dichrostachys cinerea	Sh	15	325.3	0.021	1.300	1.26	0.1	2.7
Acokanthera schimperi	Sh	14	309.3	0.043	1.213	1.20	0.2	2.7
Acacia seyal	T	5	30.0	0.341	0.433	0.12	1.9	2.5
Acacia albida	T	19	11.3	0.105	1.646	0.04	0.6	2.3
Boswellia neglecta	T	11	30.7	0.204	0.953	0.12	1.1	2.2
Grewia schweinfurthii	Sh	5	208.0	0.025	0.433	0.81	0.1	1.4
Acacia etbaica	T	10	7.7	0.072	0.867	0.03	0.4	1.3
Commiphora schimperi	T	10	18.0	0.058	0.867	0.07	0.3	1.3

5.7. Ethnobotany

Based on one of the objective of this study ethnobotanical information on the plant species used for food, forage (livestock and elephant), medicinal (human and livestock), construction & furniture, fencing, fuel and other uses were documented. Out of the total plant species documented in the study area, the local community use 32 species as food plants, 43 species as human medicinal plants, 59 species for forage, 20 species as veterinary medicine, 28 species for construction and craft, 18 species as fuel (fire wood and charcoal), 8 species as spice and condiments, 8 as cash species (where plant products have market value) and 38 species for other uses like cleansing, fumigation, perfume, fragrance, pesticides, fixatives and cultural use (like wedding, farming, funeral etc.) (Table 11).

Table 11. Taxonomic rank and category of plant species used by the local community.

Taxonomic rank	Plants used by the local community							
	Food	Forage	Medicine (Human &livestock)	Construction & craft	Fuel	spice	Market value*	others
Families	13	21	28	13	13	8	5	21
Genera	19	39	41	18	17	8	8	27
Species	**32**	**59**	**54**	**28**	**18**	**8**	**8**	**38**

*where the plant products like fruits, gum are sold in the local market.

5.7.1. Food plants

A total of 32 plant species that belong to 19 genera and 13 families are used as food in the study area (Appendix 5). Out of these 12 (37.5%) are trees, 3 (9.4%) are shrub/tree, 15 (46.9 %) are shrubs, 1 (3.1%) is a climber and 1 (3.1%) is a herb (Table 12).
From the part used for food, fruits score the highest i.e. 77.4% and gum the second 13%.

Table 12. Habit of food plants

Habit	No. of families	No. of species	Percentage
Tree	8	12	37.5
Shrub/tree	3	3	9.4
shrub	8	15	46.9
climber	1	1	3.1
Herb	1	1	3.1

Informants were asked to rank 7 edible plant species for their good taste and their own perception of quality. The scores given to each species were added and the highest score was ranked to be first. Accordingly, *Opuntia ficus-indica, Tamarindus indica and Balanites aegyptiaca* scored first, second and third respectively (Table 13). *Oncoba spinosa* ranked last.

Table 13. Preference ranking for the most popular food plants

Species name	Respondents															Score	Rank
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Opuntia ficus-indica	6	6	7	7	7	7	5	5	5	6	7	7	6	5	7	93	1
Tamarindus indica	4	5	7	6	5	6	5	5	6	6	6	7	7	7	5	87	2
Acacia Senegal	3	3	3	4	3	4	2	2	2	3	3	4	4	4	3	47	6
Balanites aegyptiaca	5	5	6	6	6	5	4	4	4	5	5	6	5	4	6	76	3
Oncoba spinosa	2	2	3	2	2	3	3	3	3	4	2	3	3	2	3	40	7
Ziziphus spina-christi	3	4	3	4	4	4	3	3	4	4	5	3	4	3	4	55	5
Berchemia discolor	5	5	5	5	6	6	4	4	3	5	6	5	5	4	5	73	4

5.7.1.1. Description of the most popular wild food plants in the study area

Opuntia ficus-indica (L.) Miller. Belongs to the family Cactaceae and the local name is Tinii (Or). Succulent spiny shrub or small tree up to 5 m high. It is widely distributed in arid, semi-arid and humid areas and growing at altitude up to 2400 m (Edwards *et al,* 2000). The fruits are edible (Zemede Asfaw, 1997). In the Babile area the ripe fruits of *O. ficus-indica* are highly edible and sold in the local markets. In the BES when the fruit ripen there is a big competition between the local community (for consumption and sale in the local market), the camels and resident elephants. The stand of this species form thicket in many part of the sanctuary and the large white spins of the plant have burring and etching effect on the skin, however, women are experts in collecting the fruits with in that dense stand for local market.

Tamarindus indica L. Belongs to the family Fabaceae and the vernacular name is Roka (Or). It is a tree up to 24m high. Growing in grassland, woodland and Combretum bushland, and riverine forest at altitudes between 0-1500m. In Ethiopia the distribution is in Tigray, Gonder, Welo, Gojam, Shewa, Hararge, Illubabor, Kefa Gamo Gofa and Sidamo. In Ethiopia and Africa fruits are edible and some times cultivated (Azene Bekele *et al.,* 1993; Zemede Asfaw, 1997). In the study area the fruits are eaten and soled in the

local market. In addition, the local communities are using the fruit as medicinal plant for abdominal disorders and intestinal parasites.

Balanites aegyptiaca (L.) Del. var *aegyptiaca*. It belongs to a family Balanitaceae and the vernacular name is Bedenno (Or). It is a multi- branched, spiny tree that grows up to more than 10 m high. Growing at altitude between 700-1800 m. In Ethiopia widely distributed in Tigray, Welo, Shewa, Arsi, Hararge, Illubabor, Gamo Gofa, and Sidamo (Sands, 1989). *B. aegyptiaca* is known for its value of provision of firewood and high quality charcoal, and oil from the kernel. In addition, the fruit pulp may be eaten raw or made into cakes and used for the preparation of an alcoholic drink (Younis, 1997). In Ethiopia during period of food shortage, young succulent shoots and leaves are cooked and eaten like cabbage (Amare Getahun, 1974) and ripe fruits are eaten raw (Sands, 1989; Zemede Asfaw, 1997). In the BES the ripe fruits are eaten widely. Despite its multipurpose function and the most important browse species, *B. aegyptiaca* faces considerable threats worldwide and its population is declining (BIC, 2002). As stated by Jones and Lyaruu (2006), in the Serengeti ecosystem *B. aegyptiaca* is likely to be affected since the ecosystem is known to have a big number of browsers. In the BES this species seems threatened since 31 individuals/ha are calculated and having relative density of 0.12.

Berchemia discolor (Klotzsch) Hemsl. It belongs to a family Rhamnaceae and the vernacular names are Jejeba (Or) & Dhen (S). It is a tree up to 8 m high. Occurring in riverine forest, *Acacia-commiphora-Balanites* woodland, wooded grassland, at altitudes between 800-1900 m. In Ethiopia the distribution is in Harerge, Bale, Gamo gofa, Shewa, Welo. The ripe fruit is edible (Vollosen, 1989; Azene Bekele *et al*., 1993; Zemede Asfaw, 1997). In the Babile area ripe fruits are eaten raw and sold in the local market. The species has been reported to be rare from time to time elsewhere from East Africa to South Africa and Namibia, Madagascar and Arabia (Vollesen, 1989). In the BES this species is highly threatened due to its multipurpose function. Its density in the study area is only 15.3 individuals/ha and relative density is 0.06.

Ziziphus spina-christi (L.) Desf. It belongs to a family Rhamnaceae and the vernacular names are Kurkura (Or) & Geb (S). Spiny tree 8-15 m, occurring in *Acacia-Terminalia, Acacia-Balanites* woodlands and bushland and riverine at altitude between 700-2100 m. It is common in Gonder, Gojam, Welo, Shewa, Arsi, Illubabur, Gamo Gofa, Bale, Sidamo and Hararge. It is widely distributed in arid parts of tropical and South Africa, Madagascar and Arabia (Vollesen, 1989). The local community in the study area use is as source of food and income by saling the fruit in the local market. The fruit is sweet so preferred more by children and youngsters in the study area. Else where in Ethiopia and other places ripe fruits are edible (Vollesen, 1989b; Azene Bekele *et al.,* 1993; Zemede Asfaw, 1997).

Oncoba spinosa Forssk. It belongs to a family Flacortiaceae and the vernacular name is Jilbo (Or). It is spiny tree up to 6 m high, growing in dry evergreen woodland, on steep valley, along riverbanks and hillsides. It is found in Tigray, Welo, Shewa, Hararge, Bale, Sidamo, Illubabor, and Kefa. Elsewhere in Ethiopia, the ripe fruits are eaten (Zemede Asfaw, 1997). The children in the BES eat the ripe fruit by breaking the hard cover and the women collect the fruit and sale in the nearest local market places. The population of this species is very small in the study area. It was observed in one community of the riverine forest and having density of 7 individuals per hectare.

5.7.2. Medicinal plants

The local communities in the study area make use of 54 species of medicinal plants in to 41 genera and 28 families for both human and livestocks. Out of these 43 plant species are used for human ailment (Appendix 6) and 20 species are used as remedies for livestock (Appendix 8) where 9 plant species are common for both human and livestock. Out of the total medicinal plants trees species are 14(26%), shrub/trees 2 (3.7%), shrubs 21(38.8%), climbers 4 (7.4%) and herbs 13 (24.1%) (Table 14).

Table 14. Habit of human and livestock medicinal plants

Habit	No. of Family	No. of species	Percentage
Trees	9	14	26
Shrub/trees	2	2	3.7
Shrubs	13	21	38.8
Climbers	3	4	7.4
Herbs	9	13	24.1

5.7.2.1. Medicinal plants for humans

A total of 43 medicinal plant species used by humans in to 32 genera and 24 families were documented. Fabaceae has the highest number of species (12 species) followed by Tiliaceae and Capparidaceae each 3 species, Balanitaceae, Euphorbiaceae, Malvaceae and Acanthaceae each 2 species and the rest 17 families each 1 species. Concerning their habit shrubs are 16 (37.2%) species, trees 14 (32.6%) species, herbs 8 (18.6%) species, climbers 3 (7%) species, and shrub/trees are 2 (4.6%) species.

From the plant parts used, leaf accounts 40%, root 24%, bark and fruit each 10%, stem 8%, fluid extract 4%, and gum and flower 4% each (Table 15).

Table 15. Habit and part used of human medicinal plants

Habit	Plant part used							
	Leaf	**Stem**	**Root**	**Bark**	**Fluid**	**Gum**	**Fruit**	**Flower**
Tree	4	0	4	4	0	0	3	1
Shrub/tree	1	1	0	0	0	0	0	0
Shrub	10	2	3	1	1	1	1	0
Climber	2	0	2	0	0	0	0	0
Herb	3	1	3	0	1	0	1	0
Percentage	**40**	**8**	**24**	**10**	**4**	**2**	**10**	**2**

Medicinal plants, which are more popular and widely used by the local community, were assessed and five human medicinal plants were selected based on the corresponding number of informants who cited the medicinal value of each species and preference ranking was done (Table 16). *Acacia senegal*, and *Aloe pirottae* were cited by 37

informants, *Euphorbia abysssinica* was cited by 33 informants, *Acacia robusta* by 28 and *Tamarindus indica* by 26 informants.

Table 16. Preference ranking for the most preferred human medicinal plants

Species name	Respondents															Score	Rank
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Acacia senegal	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	75	1
Aloe pirottae	3	5	4	3	4	5	5	5	3	4	5	4	5	5	4	64	2
Euphorbia abyssinica	3	2	4	4	5	3	2	2	4	3	3	4	5	3	2	49	4
Acacia robusta	3	2	2	3	4	3	4	4	3	3	2	3	2	2	3	43	5
Tamarindus indica	5	4	5	2	3	2	5	2	3	5	4	3	2	3	4	52	3

About 26 different health problems confronting human were documented in the study area (Table 17). Accordingly, 11 plant species are used for treatment of abdominal pain and intestinal parasite, 7 species for wound & infection and 6 species for treatment of malaria.

Table 17. Major types of human diseases and number of plant species used

Type of disease	No. of species	percentage
Abdominal pain & internal parasite	11	15.7
Wound & infection	7	10.0
Malaria	6	8.6
Snake bite	4	5.7
Ear infection	3	4.3
Eye diseases	3	4.3
Skin fungus	3	4.3
Liver diseases	3	4.3
Swelling with pus	3	4.3
Tropical ulcer	3	4.3
Bone and joint pain	2	2.9
Constipation	2	2.9
Kidney infection	2	2.9
Mouth infection & small	2	2.9
Vomiting	2	2.9
Bad sprit	1	1.4
Sexual Transmitted Disease (STD)	1	1.4
Headache	1	1.4
Heart disease	1	1.4

Hemorrhoid	1	1.4
Infertility	1	1.4
Insect bite	1	1.4
Paralysis	1	1.4
Rh disease	1	1.4
Sexuality	1	1.4
Poor sight	1	1.4

Local communities employ several methods of preparation for medicinal use such as crushed & pounded, concoction, smoke bath, eaten raw, hot infusion, fluid extract, decoction, ointment, rubbed, syrup, chewed, cream, and others (Table 18).

Table 18. Preparation methods of human medicinal plants by the local community.

Method of preparation	Total species	Percentage
Crushed & pounded	21	31.8
Concoction	15	22.7
Smoke bath	6	9.1
Eaten raw	5	7.6
Hot infusion (boil & drunk)	5	7.6
Fluid extract	3	4.5
Decoction	2	3.0
Ointment	2	3.0
Rubbed	2	3.0
Syrup	2	3.0
Chewed	1	1.5
Cream	1	1.5
Others	1	1.5

The local communities use different routes of administration. Both internal and external routes are used almost equally i.e. 51.5% and 48.55 respectively. From the internal route thee most commonly used route of administration is oral that accounts 82.4% and that of external is dermal which accounts 50% (Table 19).

Table 19. Route of administration of human medicinal plants.

Internal	total	%	External	Total	%
Oral	28	82.4	Dermal	16	50.0
Anal	3	8.8	Smoke bath	6	18.8
Eye	2	5.9	Herbal bath	5	15.6
Vaginal	1	2.9	Chew & spit	4	12.5
Others	0	0.0	others	1	3.1
Total	34	100		32	100

5.7.2.2. Medicinal plants for livestocks

A total of 20 plant species that belong to 19 genera and 14 families were recorded as having ethnoveterinary use (Appendix 8). These species were recorded along with their habit, part used, disease treated, method of preparation and route of administration. Shrubs account 45%, herbs 25%, trees 20%, and climbers 10% (Table 20).

Table 20. Habit of ethnoveterinary plant species

Habit	No. of species	Percentage
Shrub	9	45
Tree	4	20
Climber	2	10
Herb	5	25
Total	20	100

For the plant parts used, leaf constitutes 57.7%, sap 3.8% and root & fruit equal proportion i.e. 19.2% each.

About 14 different health problems confronting livestocks were documented. The most common disease of livestock in the study area is wound in which 8 plant species are used for the treatment followed by eye disease which is treated by 4 species and swelling treated by 2 species (Appendix 8).

5.7.3. Forage plants

A total of 59 plant species that belong to 21 families and 39 genera are documented as forage plant species (Appendix 9). Out of these 16 species belong to Fabaceae that constitute 27.1% and 10 species belong to Poaceae that constitute 17% of the forage species. In general, about 45% of the forage species are Fabaceae and Poaceae. Shrubs constitute the highest percentage and followed by trees and grasses (Table 21).

Table 21. Habit of forage plants

Habit	No. of families	No. of species	Percentage
Tree	6	12	20.3
Shrub/tree	1	1	1.7
shrub	10	22	37.2
climber	5	5	8.5
Herb	8	9	15.3
Grass	1	10	16.9

5.7.4. Multipurpose plant species

Many woody plant species have multiple uses in the study area. Direct matrix ranking was done for the ten woody species that were cited by more than 50% of the informants as a multipurpose plant species. Food value, forage value, medicinal value, construction & crafts value, firewood & charcoal use and market value of the plant products were considered to measure the multiple use of a give species.

The result from direct matrix ranking shows *Tamarindus indica* scores the first rank and followed by *Berchemia discolor and Balanites aegyptiaca* (Table 22).

Table 22. Direct matrix ranking for multi-purpose woody species

Species name	Value						total	Rank
	Food	Forage	medicinal	Construction & crafts	Firewood & charcoal	Market* value		
Acacia senegal	6	5	10	2	6	5	34	7
Tamarindus indica	8	8	9	8	6	9	48	1
Opuntia ficus-indica	10	9	4	1	1	10	35	6
Acacia robusta	1	8	7	10	10	1	37	4
Balanites aeygptiaca	7	8	7	7	8	1	38	3
Berchemia discolor	7	8	1	10	10	8	44	2
Acacia bussei	1	7	1	8	8	1	26	10
Acacia tortilis	5	9	6	8	8	1	37	4
Acacia etbaica	1	8	1	8	8	1	27	9
Commiphora erythraea	1	6	7	6	7	2	29	8

*Market value refers for the value of any product from the plant (Fruit, gum & resin, etc) on the local market.

5.7.4.1. Population structure of top ten multi-purpose woody plant species

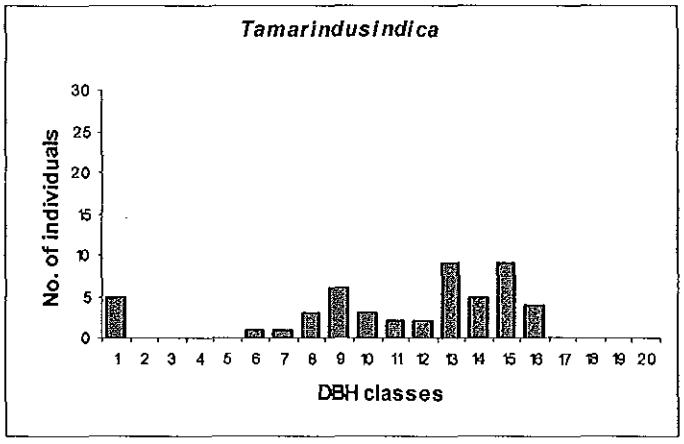
Population structure of the ten multi-purpose woody species reveals four main patterns of population distribution (Fig. 11).

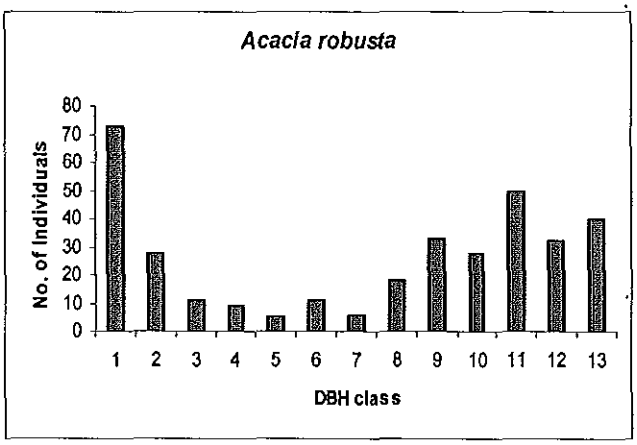
I) An inverted J-shaped, which shows a pattern where species frequency distribution has the highest frequency in the lower diameter classes and a gradual decrease towards the higher DBH classes e.g., *Acacia senegal, Opuntia ficus indica, Acacia bussie, Commiphora erythraea,* and *Acacia tortilis.*

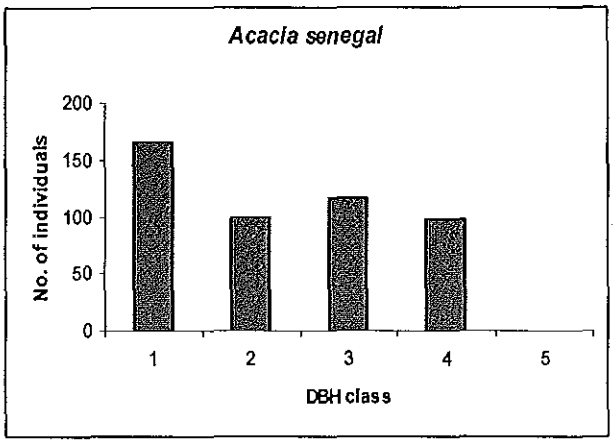
II) Broken inverted J-shaped e.g., *Acacia etbaica* and *Berchemia discolor.*

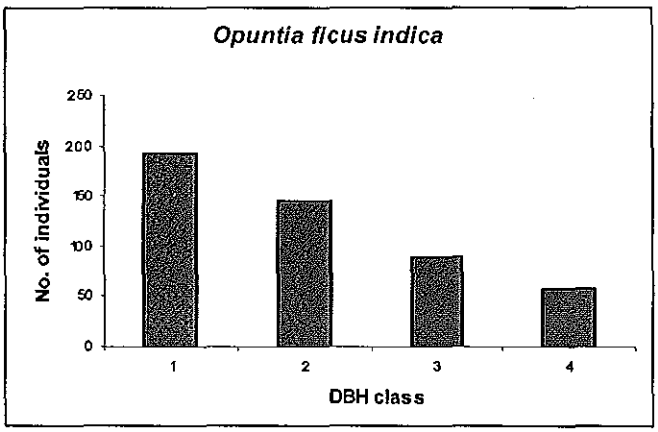
III) U-shaped, this shows a type of frequency distribution in which there is a high number of lowest and highest diameter classes but a very low number in the intermediate classes e.g., *Acacia robusta* and *Tamarindus indica.*

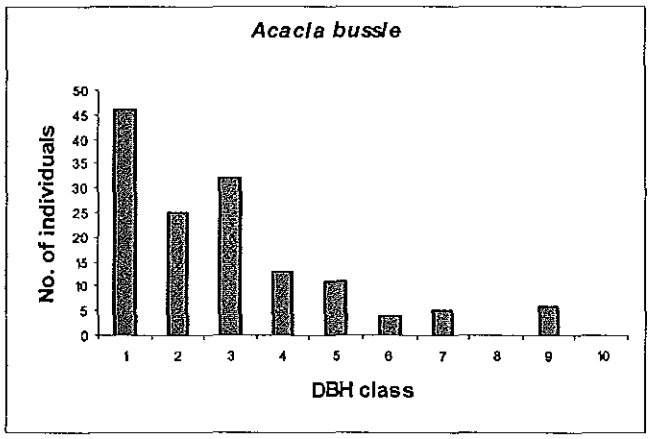
IV) Bell-shaped, which is a type of frequency distribution in which number of individuals in the middle diameter classes is high and lower in lower and higher diameter classes e. g., *Balanites aegyptiaca.*

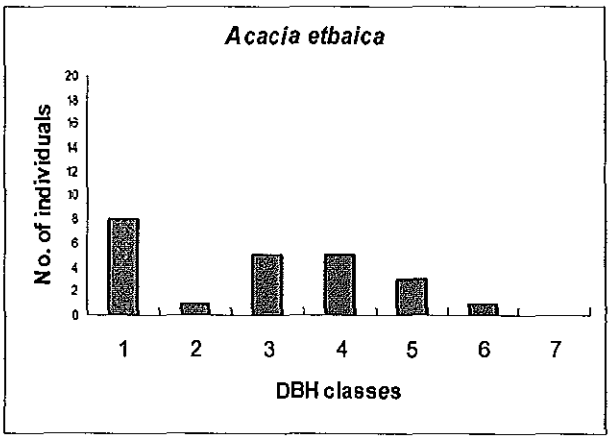


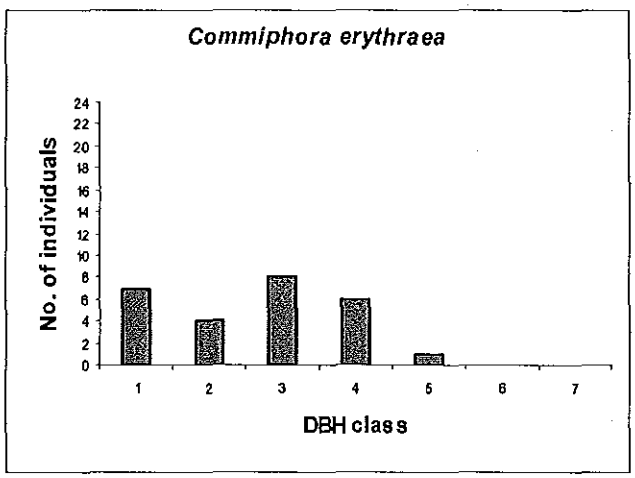


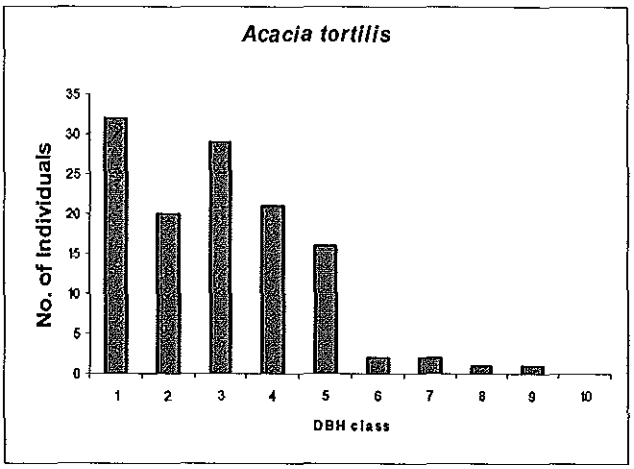

Acacia senegal
No. of individuals
200
150
100
50
0
1
2
3
4
5
DBH class


Opuntia ficus indica
No. of individuals
250
200
150
100
50
0
1
2
3
4
DBH class


Acacia bussie
No. of individuals
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
DBH class


Acacia etbaica
No. of individuals
1
2
3
4
5
6
7
DBH classes


Commiphora erythraea
No. of individuals
24
22
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
DBH class


Acacia tortilis
No. of individuals
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
DBH class

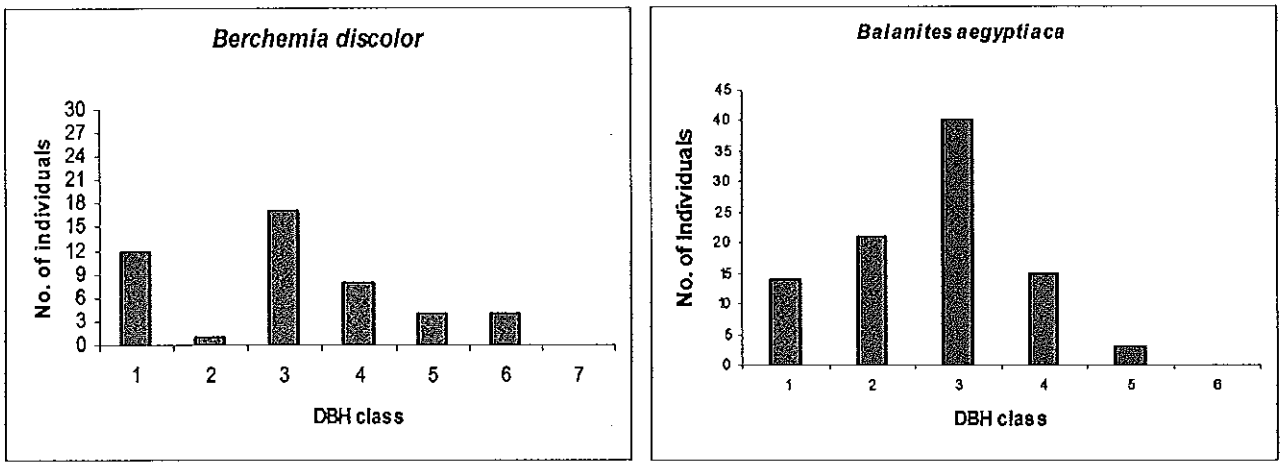


Fig. 10. Diameter class frequency distribution of multi-purpose tree species. (DBH class: 1 = 1-4.99 cm; 2 = 5-9.99 cm, 3 = 10-14.99 cm, 4 = 15-19.99 cm, 5 = 20-24.99 cm, 6 = 25-29.99 cm, 7 = 30-34.99 cm, 8 = 35-39.99 cm, 9 = 40-44.99 cm, 10 = 45-49.99 cm...)

5. 8. Woody species browsed by elephants

A total of 24 plant species belong to 12 families were identified as browsed by elephants (Table 23). Out of these 11 (45.8%) trees and 13 (54.2%) were shrubs. The total density of the 24 woody species is 11559.6 individuals ha^{-1}. The mean density is 481.6 ± 282.5 (SE), where the maximum density is 6842.7 individuals/ha (*Opuntia ficus-indica*) and the minimum density is 3.7 individuals ha^{-1} (*Salvadora perisca*). The total density of trees is 492.8 individual/ha and shrubs 11066.8 individual ha^{-1}. Shrubs account 95.7% where as trees only 4.3% of the total density of these 24 woody species.

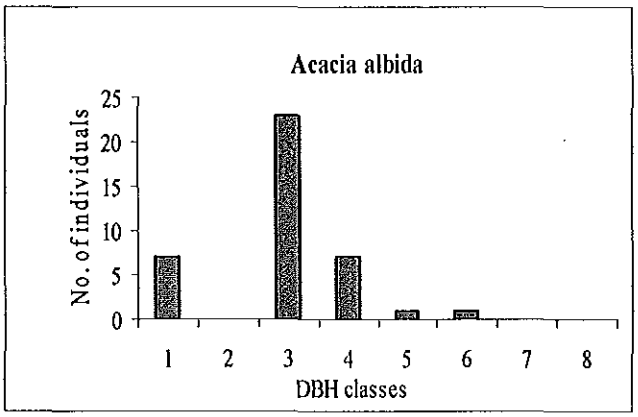
Table 23. Important Value Indies (IVI) of the 24 woody species browsed by elephants (T = tree, Sh = shrub; Cl = climber)

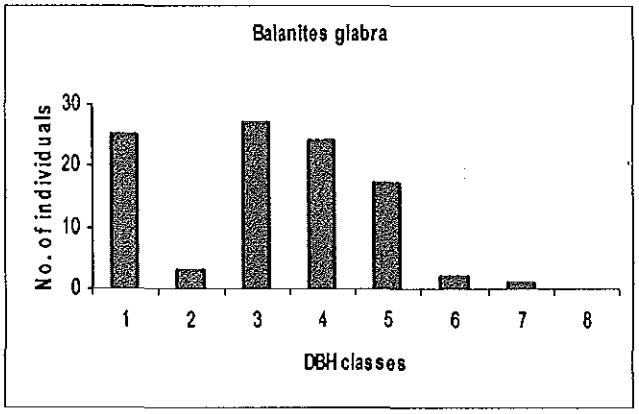
Scientif name	Habit	freq	Dens/ha	BA m^2/ha	Rfre	Rden	Rdom	IVI
Acacia robusta	T	15	100.7	7.006	1.300	0.39	39.3	41.0
Opuntia stricta	Sh	57	3842.7	0.963	4.939	26.50	5.4	36.8
Tamarindus indica	T	5	15.7	2.462	0.433	0.06	13.8	14.3
Opuntia ficus-indica	T	50	216.7	1.130	4.333	0.84	6.3	11.5
Acacia mellifera	Sh	50	1274.7	0.260	4.333	4.94	1.5	10.7
Acacia tortilis	T	36	41.3	0.702	3.120	0.16	3.9	7.2
Balanites glabra	T	33	33.7	0.369	2.860	0.13	2.1	5.1
Grewia ferruginea	Sh	32	496.0	0.020	2.773	1.92	0.1	4.8

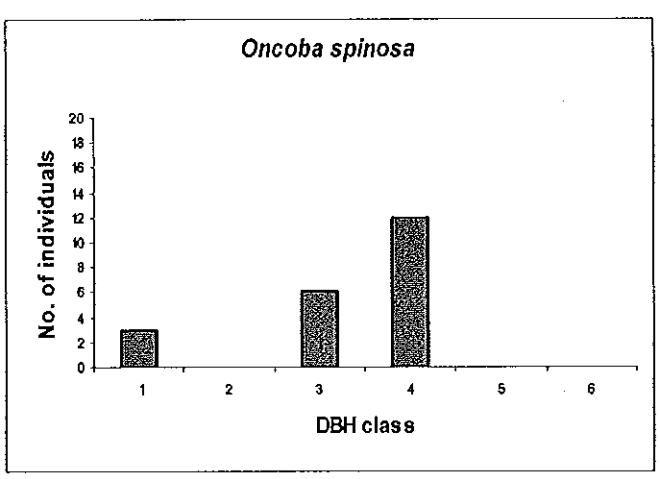
Kleinia squarrosa	Sh	32	496.0	0.013	2.773	1.92	0.1	4.8
Balanites aegyptiaca	T	28	31.0	0.262	2.426	0.12	1.5	4.0
Cryptostegia grandiflora	Cl	19	448.0	0.012	1.646	1.74	0.1	3.5
Grewia bicolor	Sh	20	410.7	0.015	1.733	1.59	0.1	3.4
Berchemia discolor	T	17	15.3	0.268	1.473	0.06	1.5	3.0
Dichrostachys cinerea	Sh	15	325.3	0.021	1.300	1.26	0.1	2.7
Acokanthera schimperi	Sh	14	309.3	0.043	1.213	1.20	0.2	2.7
Acacia albida	T	19	11.3	0.105	1.646	0.04	0.6	2.3
Acacia etbaica	T	10	7.7	0.072	0.867	0.03	0.4	1.3
Acacia oerfota	Sh	6	122.7	0.038	0.520	0.48	0.2	1.2
Euclea schimperi	Sh	4	154.7	0.001	0.347	0.60	0.0	1.0
Carissa spinerum	Sh	5	112.0	0.003	0.433	0.43	0.0	0.9
Oncoba spinosa	T	5	7.0	0.073	0.433	0.03	0.4	0.9
Salvadora persica	T	5	3.7	0.038	0.433	0.01	0.2	0.7
Dodonaea angustifolia	Sh	4	74.7	0.003	0.347	0.29	0.0	0.7
Acacia nilotica	T	5	8.7	0.020	0.433	0.03	0.1	0.6

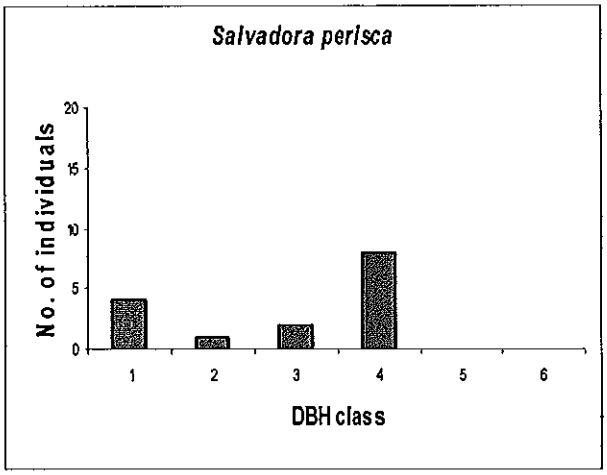
5.8.1. Population structure of dominant woody species browsed by elephants

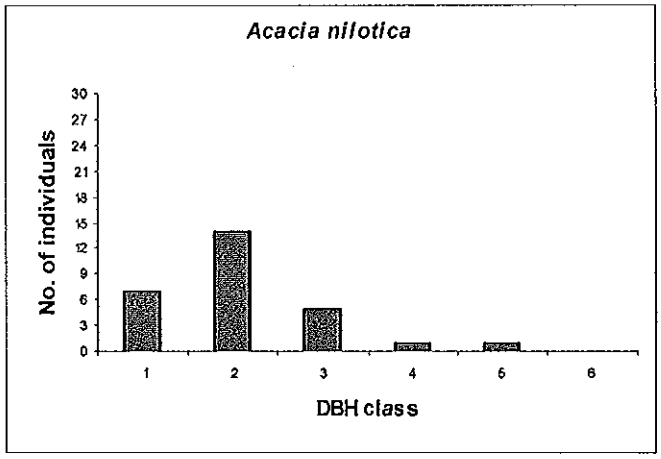
The population structure of the tree species exhibited inverted J-shaped, broken inverted J-shaped, U-shaped and bell-shaped frequency distribution. Whereas, the shrubs exhibited an inverted J-shaped frequency distribution (Fig. 12). See Fig. 11. for population structure of *Acacia tortilis, Acacia etbaica, Balanites aegyptiaca, Berchemia discolor* and *Tamarindus indica.*











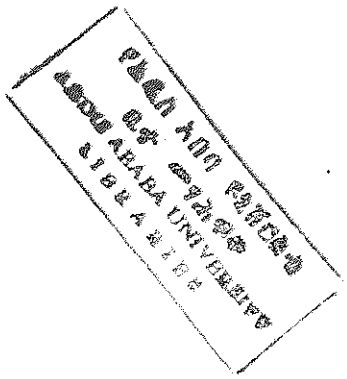


Fig. 11. Diameter class frequency distribution of ten top woody species browsed by elephants (DBH class: 1 = 1-4.99 cm; 2 = 5-9.99 cm, 3 = 10-14.99 cm, 4 = 15-19.99 cm, 5 = 20-24.99 cm, 6 = 25-29.99 cm, 7 = 30-34.99 cm, 8 = 35-39.99 cm, 9 = 40-44.99 cm, 10 = 45-49.99 cm...).

5.8.2. Regeneration status of trees and shrubs browsed by elephants

The total density of germinants, seedling and sapling of these woody species was 3377 individuals ha^{-1}. Out of this germinants, seedling and sapling was 173 (5.5%) individuals ha^{-1} and the germinants and seedlings of shrub/climbers was 3204 (94.5%) individuals ha^{1}.

A total of 19 woody species were analyzed to know the regeneration status of trees and shrubs browsed by elephants. Top browsed trees like *Acacia robusta* (*47* individuals ha^{-1}), *Balanites aegyptiaca* (*17* individuals ha^{-1}), individuals ha^{-1}), *B. glabra* (*24* individuals ha^{-1}) and *Acacia tortilis (18* individuals ha^{-1}) show relatively better regeneration among the tree species (Fig.13). Among the shrub species *Acacia mellifera* (342 individuals ha^{-1}), *Dichrostachis cinerea* (112 individuals ha^{-1}), *Grewia ferruginea* (112 individuals ha^{-1}) and *Grewia bicolor* (96 individuals ha^{-1}) has good regeneration than other species (Fig. 14).

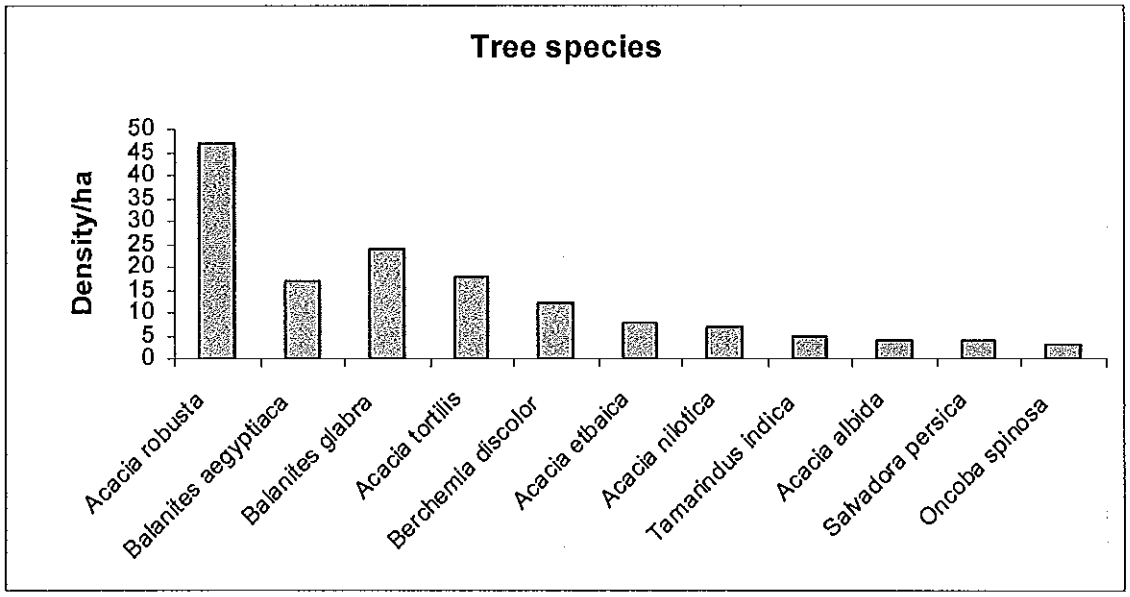


Fig. 12. Regeneration density per hectar for top ten tree species browsed by elephants

Among the shrub species *Acacia mellifera* (342 individuals ha^{-1}), *Dichrostachis cinerea* (112 individuals ha^{-1}), *Grewia ferruginea* (112 individuals ha^{-1}) and *Grewia bicolor* (96 individuals ha^{-1}) has good regeneration than other species (Fig. 14).

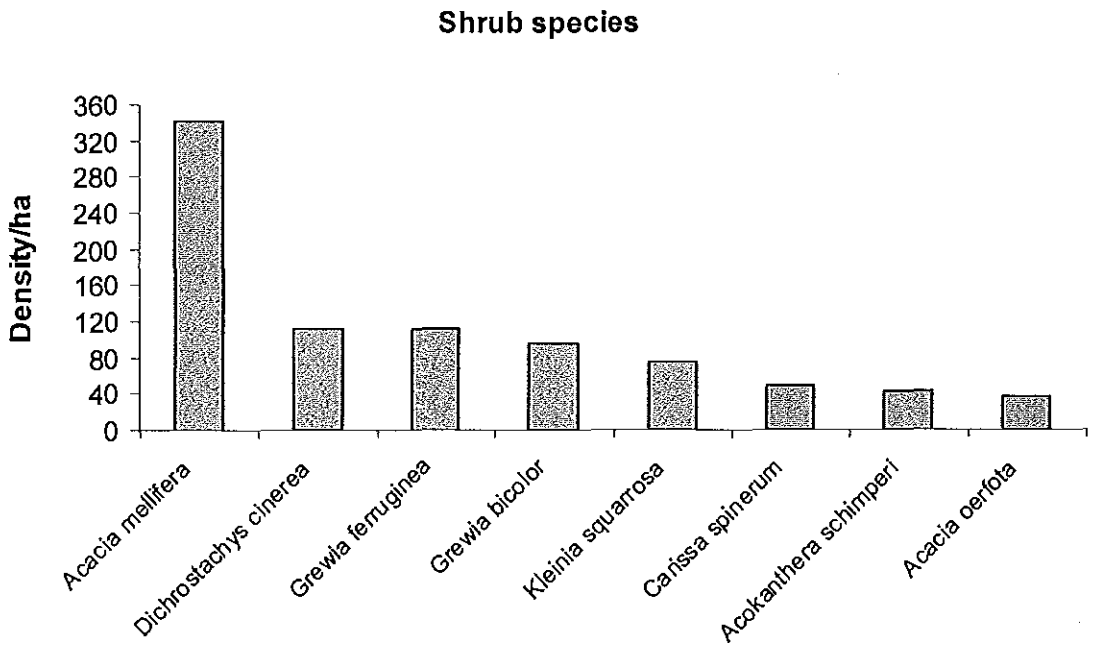


Fig. 13. Regeneration density per hectare for ten top shrubs browsed by elephant

5.9. The major anthropogenic impacts in the BES

Temporary and permanent settlement, charcoal making, firewood collection, overgrazing, deliberate fire to clear for agriculture, and selective tree cutting for construction are the main threats in the sanctuary. Agriculture scores 5 which is the major threat for the sanctuary, human settlement and overgrazing 4, charcoal making and tree cutting 3, invasive species 2, and honey collection 1, in which the second, third, fourth and fifth threats respectively for the sanctuary.

Approximately about 400 hectares of land along the river Erer have been used for agriculture illegally. A total of 31 small villages were counted in the sanctuary. Even during the data collection period, a total of 20 hectares of woodland were cleared (burned) in the different part of the Erer valley and prepared for illegal agriculture where 251 tree cuts were counted from one area and reported for the Babile Wereda (Fig. 15).

Fig.14. How people are clearing the *Acacia seyal* woodland with fire for agriculture.

Within the three months data collection period about 735 sacks of charcoal produced, 625 bundles firewood cutted, and 680 trees cutted for house construction per month in the Erer valley.

Invasive species like *Lantana camara* and *Parthenium hystrophorus* are the other threat for the vegetation of the sanctuary. Out of the total quadrats (75) *L. camara* was recorded in 43 quadrats. In addition the density of *L. camara* was 2794.6 individuals per ha. Where 1034.6 individuals/ha are germinants (<0.1m ht) and seedlings (0.1 up to 0.5 m ht) which accounts 37% of its total density.

6. Discussion

6.1. Floristic composition

A total of 237 plant species in 155 genera and 57 families were identified. Direct comparison of the species diversity with other natural vegetation may not be feasible due to differences in size of the study area, survey methods and objectives. However, the overall species richness of a given vegetation type can give a general impression of their diversity (Tadesse Woldemariam, 2003). In this regard, the species richness in the Erer valley/Babile Elephant Sanctuary was higher than the near by valley, Daketa valley, which was reported 202 species in to 54 families by Demel Teketay (1995) and Nechsar National park where 199 plant species was reported in to 42 families by Tamirat Andargie (2001). As compared to the Gara Muleta mountain (Western boarded of the BES) vegetation which was reported 361 plant species in to 82 families by Demel Teketay (1996), and Abaya-Hamassa *Acacia-Commiphora* woodland vegetation which was reported 315 species in to 59 families (Eyasu Chama, 2005), the study area has less species richeness.

As the analysis about the species distribution by family indicate, the families such as Fabaceae, Malvaceae, Tiliaceae, Euphorbiaceae, Boraginaceae, Capparidaceae, Anacardiaceae, and Burseraceae are reperesented by a large number of species. Such floristic composition was explained as one major feature in the *Acacia-Commiphora* deciduous bushland and thicket. According to White (1983), although there is appreciable variation in floristic composition, in this formation type species of *Acacia, Commiphora, Capparis* and *Grewia* are nearly always present.

The characteristic plant species in *Acacia-Commiphora* (small-leaved deciduous) woodland include drought tolerant trees and shrubs; *Acacia tortilis, Acacia mellifera, Balanites aegyptiaca*, species of *Acalypha, Aerva, Barleria, capparis, Combretum, Terminalia*, etc (Demel Teketay, 1999; Friis and Sebsebe Demissew, 2001). This vegetation type occurs mainly in southern and eastern parts of the country and the rift valley (Demel Teketay, 1999). In the BES from the *Acacia* (small-leaved deciduous)

woodland species of *Acacia tortilis, Acacia mellifera, Balanites aegyptica, Acalypha fruticosa, Barleria eranthemoides, Capparis sepiaria, Capparis tomentosa, Combretum molle, and Terminalia brownie* were recorded, actually having different relative abundance value.

The floristic list from the riverine forest consist of trees and shrubs species like, *Acacia robusta, Tamarindus indica, Oncoba spinosa, Acokanthera schimperi*, and *Capparis tomentosa.* Plant species such as, *Acacia robusta, Tamarindus indica, Acokanthera schimperi*, and *Capparis tomentosa* are the characteristic species on the banks of the rivers in the Somalia-Masai riparian forest (White, 1983).

The floristic list, the climate and altitude range of the study area may reveal, the BES has *Acacia-Commiphora* deciduous bushland and thicket, *Acacia-Commiphora –Terminalia* woodland, and riverine forest vegetations in its diverse nature over short distance. According to Walter (1971), vegetation is characterized by the link between individual species distribution patterns, their occurrence in landscape features, and the distribution of the landscape features. The study area has an altitudinal range between 850 m and 1750 m, which is within the altitudinal range of *Acacia-Commiphora* bushland and thicket and *Acacia* woodlands in Ethiopia.

Fabaceae, Poaceae and Asteraceae are the three most dominant families having 70 species that account about 30% of the floristic composition. This may show the suitability of the sanctuary for herbivory by both the wildlife and the livestocks. In his assessment of forage species, Gemedo Dalle *et al.*, (2005) reported that the families Fabaceae, Poaceae, Asteraceae and Lamiaceae account 51% in the Borena lowland where the highest livestock populations of the country exist. The family Fabaceae ranks first that comprises drought tolerant, deciduous and spiny species that are well established to the prevailing drought conditions of the study area. Several studies in the Ethiopian rift valley and Borena lowlands also reported Fabaceae as the dominant family in terms of species composition (Beals, 1969; Debela Hunde *et al.*, 2004; Zerihun Woldu *et al.*, 1999; Gemedo Dalle *et al.*, 2005)

According to Beals (1969), the abundance of Acantaceae in part of the Erer Gota was explained as an indicator of overgrazing. In the sanctuary, about 14 species of Acantaceae were documented. Observed condition of the vegetation in the riverine and deciduous bushlands, where most of these species were collected, strongly suggested that indeed these vegetation stands suffer more from grazing.

6.2. Community types

Plant species are the building blocks of the plant communities that together constitute the vegetation of the different regions (Walter 1971). As stated by Mueller-Dombois and Ellenberg (1974), a plant community can be understood as a combination of plants that are dependent on their environment, influence one another, and modify their own environment. Drought tolerant trees and shrubs, with either small deciduous leaves or leathery persistent ones characterize most of the communities in the study area.

The six communities identified in this study represent groups of sites that have certain internal homogeneity in their species composition, and can be considered as distinct units in which specific management or conservation measures relevant for the major species comprising the assemblage can be made.

The species composition of community 1 and 2 are compatible with that of riverine forest where the indicator species are *Tamarindus indica* and *Acacia robusta* respectively. Interms of spatial distribution, the riverine forest is the least distributed however, the sampled quadrats were formed two communities that shows internal heterogeneity. Expansion of agriculture, tree cutting, and over browsing are the serious impacts affected these communities. These two communities show major difference from the other four communities. Environmental factors such as altitude, landforms, soil type, and moisture, may contribute for this remarkable difference.

Community 3, 5 and 6 are from the woodland where *Acacia tortilis-Balanites aegyptiaca, Terminalia brownia-Boswellia neglecta* and *Acacia bussie* are the dominant species of these communities respectively. These community types were stratified as one formation type at the beginning of the study. The sampled quadrats from 5 different sites of the woodlands were clustered in to three groups forming three plant communities. This shows the internal heterogeneity in a woodland of the study area. Soil, altitude, surface feature and anthropogenic factors may contribute for the difference in species composition among these community types. For example the dominant surface feature in Communities 5 and 6 is rocky where as community 3 is sandy soil. Community 5 have more west facing hillsides where as Community 6 have east facing hillsides that can be considered as environmental factor contribute for the difference in species composition.

Community 4 is from the bushland and thicket that occupies the largest part of the sanctuary. This community was stratified as one formation type at the beginning of the study. All the quadrats from 4 different sites of the bushland and thickes were clustered in to one group forming one plant community where the dominant species are *Acacia senegal* and *Acalypha fruticosa.* This might be due to the internal homogeneity in the bushland and thicket than the woodlands of the study area. Even these most dominant species in this community was observed in all community types with different densities. This may show the expansion of this vegetation type in the study area which may lead to the formation of homogeneous vegetation stand throughout the sanctuary.

6.3. Species diversity

The over all species diversity value shows high value, which indicate high diversity in the study area however the evenness is less. Lower evenness indicates the dominance of few species in the area (Feyera Senbeta, 2006). Accordingly, species of *Opuntia stricta, O. ficus-indica, Acalypha fruticosa, Acacia senegal, A. mellifera* and *A. brevispica* are highly dominant in the study area.

Diversity and evenness of species in plant communities is used to interpret the relative variation of the community indices and explain the underlying reasons for the differences

among communities. The six communities showed variation in their species richness, evenness and diversity (Table 6). This difference is the function of different factors. Habitat heterogeneity, disturbance and edaphic factors may contribute more for the difference.

The highest species richness and diversity was observed in community 3. This community was from the *Acacia-Balanites* woodland. As compared to communities 1 and 2, in community 3 there is little agricultural activity and low human settlement. So the highest species richness and diversity in community 3 could probably be attributed to the intermediate level of disturbance as compared to other community types beyond the optimum environment that support the Acacia woodland species. According to the intermediate disturbance hypothesis, both high and low levels of disturbance reduce diversity while intermediate levels promote higher diversity (Rosenzweig, 1995). In terms of species evenness, community 3 is the third highest. This may be attributed to the selective cutting of trees that could resulted unevenness in species distribution. Species evenness measures the equity of species in a given sample or community (Magurran, 1988).

The second highest species richness and fourth diversity but less evenness was obtained in community 4. This shows the high level of disturbance in this community. For example, the least evenness could be explained in terms of the dominance of some species in the area. In community 4 species of *Acacai senegal, Acalypha fruticosa* and *Acacia mellifera* are the most dominant. It might be the less palatable nature, dispersal mechanisms such as wind, and/or environmental factors contribute the domination of these species in this community. However, as was observed in the field in this community, which was sampled from the bushland and thicket, very high population of livestocks was used to browse and more number of settlement villages was established. Therefore, the high-level disturbance that can lead to less evenness of this community may be the cumulative effect of these factors.

The low species richness and evenness in community 1 and 2 may be due to the high-level disturbance factors. Similarly, Feyera Senbeta (2006) stated that the low species richness and evenness in the Maji forest was due to anthropogenic disturbances, such as

burning, grazing, and wood collection. Accordingly, the highest agricultural expansion, tree cutting and over browsing along the Erer River could be explained for the reduction in the species richness and evenness in community 1 and 2. There is a significant correlation between disturbance and plant species richness (Feyera Senbeta, 2006).

According to Bormann and Keller (1991), high environmental stability leads to high community stability which inturn permits high species diversity. Invasive species like *L. camara* and *Parthenium hysterophorus* are highly observed with in these communities. This might contributed for the instability of this environment in addition to environmental factors that contribute for species diversity. The expansion of these invasive species may affected the species richness and evenness especially community 2 where *L. camara* showed the second dominance next to *A. robusta* and resulted the least species richness and evenness. Since diversity follows the trends observed in species richness and evenness (Whittaker, 1975), it is highest where there is high species richness and evenness value and lowest in species poor communities.

Community 5 and 6 are the third highest species richness, the second high diversity, and the first high evenness. These two communities are from the woodland where some parts are from the hillsides and the surface feature is rocky and sloppy. Less human disturbance was observed in these communities. Because of the surface feature and topography it is not convenient for settlement and agriculture. This might be the reason for the high evenness and diversity result for these communities. High evenness in these communities indicates little dominance by any single species but repeated coexistence of species over all quadrats. Relatively lower species richness may attributed for slope and surface features which influence run-off and drainage that can be reduced the field layers.

6.4. Similarity between community types

Sorensen's similarity coefficient analysis indicates that there is high similarity between communities 1 and 2, followed by communities 3 and 4, and communities 5 and 6 (Table 7). This may be due to the more number of common species between these pair

of communities. The sample quadrats in these high floristic similarity communities were taken from the same formation type. For example, communities 1 and 2 that show highest similarity were sampled from the riverine forest and communities 5 and 6 are from woodland. This may be the major reason for more number of common species between these communities. Least similarity was obtained between community 1 and 5, 1 and 6, 2 and 5, 2 and 6, and 1 and 4. These communities are from the different formation types i.e. riverine, deciduous bushland and open woodland vegetations, this may be the basic reason for the less Sorensen's similarity coefficient values between these communities.

The relationship between similarity coefficient and beta diversities is that they are inversely related. Low similarity coefficient indicates high beta diversity (i.e., high species turnover between the communities) and vise versa (Feyera Senbeta, 2006). The fewer the species that communities 1 and 5, 1 and 6, 2 and 5, 2 and 6, and 1 and 4 share, the higher is the beta diversity, that signify the appropriateness of stratification which was used as a methodology in the study area. Furthermore, environmental factors such as soil particles, soil texture, moisture, altitude etc are contributed for the similarities and dissimilarities in species composition between the communities.

6.5. Woody species density

Density was calculated for woody species, by calculating the average individual tree, shrub and climber count, in terms of number of individuals per hectare in each community (Fig. 5.3). The highest density of shrubs/climbers in communities 3, 4, 5 and 6 is due to the domination of small sized shrubs/climbers in the floristic composition of these communities such as *Opuntia stricta (*drought season feed*), Acalypha fruticosa, Acacia brevispica* and *Acacia senegal* which constitute about 50% of the total density. The most probable reason for the domination of these species in the floristic composition of all communities may be less palatable or unpalatable nature of these plant species by both livestocks and resident elephants in the sanctuary. Another most probable factor may be specialization of the different species to different dispersal agents. Wind can

carry light seeds with thin testa and cotyledons, e.g. *Acacia senegal*, for a considerable distance (Tybirk, 1991). Some plant species may have a wide range of dispersal mechanisms and/or rapid reproduction strategies (Feyera Senbeta, 2006). In general, in the study area, stochastic processes most likely determine the dominance of these species.

The difference in densities of woody species between riverine forest, woodlands and bushlands may attributes to the differences in size of the woody species in these three formation types. Large sized trees and shrubs (high DBH & height) was recorder from the riverine forest that may decrease the density. Medium sized woody species was recorded from woodlands where most tree species lost high DBH classes due to exploitation so the density is less than the riverine forest and the bushlands and thicket is dominated. by small sized woody species that contributed for the highest density of individuals per hectare.

The least density of the most important tree species like *Tamarindus indica, Balanites aegyptiaca, Berchemia discolor, Acacia albida, Acacia etbaica, Sterculia africana, Salvadora perisca, Commiphora erythraea, Acacia nilotica* and *Combretum molle* may show how these tree species are highly threatened in the study area (Table 10).

6.6. Basal area (BA) and Importance Value Index (IVI) of woody species

The total basal area (m^2/ha) of the woody species in the study area is 17.8. The normal value of basal area for virgin tropical forests in Africa is 23 – 37 m^2 ha^{-1} (Lamprecht, 1989). Therefore, it could be said that the basal area ha^{-1} coverage of the study area is less.

Species dominance is meant the basal area per ha coverage of each individual woody species in the forest. About 80% of the dominance was accounted by ten woody species. These are *Acacia robusta, Tamarindus indica, Opuntia ficus indica, Acacia bussei, Terminalia brownii, Acacia tortilis, Balanites glabra, Acacia seyal, Berchemia discolor* and *Balanites aegyptiaca* (Table 10). These tree species are the top browsed species by elephants as well as among the multipurpose woody species. Perhaps it is due their relatively high dominance value in the sanctuary that these species afforded the higher

feed demand of the elephants, livestocks and local community consumption. However, if the current anthropogenic threat on these tree species continues their density will lower dawn and then their dominance may not be able to support the highest feed demand of the resident elephants.

The Importance Value Index (IVI) is useful to compare the ecological significance of species (Lamprecht, 1989). Trees and shrubs with IVI > 10 are can be considered as the most important species in the BES, such as, *Acacia robusta, Opuntia stricta, Acacia senegal, Acacia brevispica, Tamarindus indica, Opuntia ficus-indica, Acacia mellifera* and *Euphorbia burgeri* (Table 10). Even if *Acacia robusta* and *Tamarindus indica* had high IVI their population structure (Fig. 5.4) showed that these tree species had U-shaped pattern that indicate selective cutting and removal of medium-sized trees.

Most multipurpose woody species like, *Acacia tortilis, Acacia bussei, Balanites aegyptiaca, Berchemia discolor, Commiphora erythraea,* and *Acacia etbaica* resulted IVI < 10. Their lower IVI may indicate that these woody species are threatened and in need of immediate conservation measure.

6.7. Ethnobotany

The result showed that forage utilization had the highest contribution to the total use followed by uses as medicinal and edible plants. There is a high degree of dependence of the local community on plant resources for forage which may reflect livestock is the main production system and the dominance of pastoralist population than agriculturalists in the study area. Medicinal value is the second most important category. Obviously, herbal medicines are very important in Ethiopia since most modern medicine are unavailable and unaffordable for most of the inhabitants.

6.7.1. Food

A total of 32 plant species in to 19 genera and 13 families are used as food in the study area. Out of these 20 species were documented by Bayafers Tamene (2000) and 12

species by Gemedo Dalle (2004). Wild edible plants were about 13.5% of the total plant species encountered in the study area. About 13% of the total plants documented in Borena Lawland are edible (Gemedo Dalle *et al.*, 2005). Zemede Asfaw and Mesfin Tadesse (2001) estimated that about 8% of the higher plant species of Ethiopia are edible. The relative high percentage of wild edible plants in the study area may be due to the more intensive utilization of plants by the local communities in this semi-arid region as compared to inhabitants in the humid or highlands. From the part used fruits score the highest i.e. 77.4% and all the fruits are eaten raw except *Salvadora perisca* where its fruit/seed is eaten cooked. This may show how simple is that the use of wild edible plants than cultivated crops.

Cattle herders are more knowledgeable in identifying and using these wild edible plants. Even most of the young cattle herders (both male and female) spent the whole day in the forest waiting under their cattle and using these edible plants like *Opuntia ficus-indica, Tamarindus indica, Berchemia discolor* and *Balanites aegyptiaca* with milk. However, according to most informants as compared to the past ten or more years, this days most of the wild edible plants are not easily accessible for the local community. Similarly, Bayafers Tamene (2000) stated that many wild food plant species are not easily accessible nowadays for the local communities due to deforestation. Those plant species, which are drastically declining in abundance from the study area, include *Tamarindus indica, Balanites aegyptiaca, Oncoba spinosa, Ziziphus spina-christi, Berchemia discolor* and *Salvadora perisca.*

The females are collecting the fruits of *Opuntia ficus-indica, Tamarindus indica* and *Oncoba spinosa* for sale in the nearest local market places such as Bisidimo, Babile, Erer towns and get reasonable income. In the different part of the country, the fruits of *Opuntia ficus indica, Tamarindus indica* and *Oncoba spinosa* are collected and sold in the local market (Zemede Assfaw, 1997; Bayafers Tamene, 2000). In the study area the fruits of *O. ficus indica* ripen two time a year i.e., after the long rain season and the short rain season. Interestingly, the plant gives more fruits after the short rain season where the local community could suffer for shortage of cultivated food plants. In

addition, plant species like *Acacia senegal, Acacia mellifera and Acacia seyal* are used during drought season and famine time. The part used is the gum which is tasteless but satisfy an immediate need of food for any one starved. As stated by Zemede Asfaw (1997), edible wild plants often help to prevent starvation during drought season.

As was mentioned by the respondents, it is an enjoyable task to collect the ripen small fruits of *Carissa spinarum, Euclea racemosa ssp. schimperi, Grewia bicolor* and *Rhus natalensis* by children and young cattle herders and use as a snake as well as to bring at home for the family. Obviously, this can be used as a supplementary food and may fill the gap in the nutrition of the local community that depends predominantly limited cultivated crops like many part of the country. As was stated by Zemede Asfaw and Mesfin Tadesse (2001), the wild edible plants are reserve foods that fill the food deficit gap and also may have future potential as food crops.

Informants were asked to rank seven edible plant species for their good taste and their own perception of quality. Accordingly, *Opuntia ficus-indica* ranked first and *Oncoba spinosa* last. May be many people preferred *Opuntia ficus-indica* due to its abundance, sweetness, more water content of the fruit and food satisfaction nature of the fruit. It is well known by all age groups of the community and has good market value. The local communities are using *Oncoba spinosa* for local market rather than using themselves. In the local community, children use it more.

6.7.2. Medicinal

6.7.2.1. Human

The document on medicinal plants include local names (Oromiffaa and Somalii names), habit, part used, medicinal use, mode of preparation and root of administration (Appendix 6). A total of 43 human medicinal plant species were documented where 12 species belongs to Fabaceae. This may be explained from the fact that Fabaceae is the highest proportion in the floristic composition of the study area. Out of 43 species documented in

this study 21 species were reported by Bayafers Tamene (2000), and 23 species were reported by Mesfin Tadesse and Sebsebe Demissew (1992).

There were still many medicinal plants available to the users. There was also broad indigenous knowledge on the use of traditional medicinal plants. The traditional system and religious beliefs that restrict the way of transferring indigenous knowledge may reduced information on medicinal plants in this study. It was observed that many young people in the study area are not knowledgeable about the variety and value of indigenous medicinal plants. According to Cunningham (1996), medicinal plant knowledge, use and transfer of knowledge to the young generation can be affected by religious beliefs, modernization, acculturation and environmental change. It was observed during this study that knowledgeable persons kept their knowledge secret. Therefore, ethnomedicinal knowledge diminishes with the death of elderly knowledgeable members of the local community.

Some plant species are used for several types of disease treatment like *Acacia senegal, Aloe sp, Acacia nilotica* and *Balanites aegyptiaca,* and different plant species are used for treatment of the same disease. In case where different species were prescribed for the same health problem, people showed preference of one to the others. As stated by Erdelen *et al.,* (1999), different plant species may be used for the treatment of the same disease or a specific ailment might be treated by a particular plant species. Different plant parts are prepared in different ways and used to treat the same type of aliment. For example, the fresh leaf and fluid extract of *Aloe pirottae* are concocted together and taken orally to treat malaria; the leaf and root of *Sarcostemma viminale* are crushed together and put at the tip of the anal opening to treat hemorrhoid.

Out of 43 plant species 11 species are used for treatment of abdominal pain and intestinal parasite (Table 16). Accordingly, the clinical report for 2004/05 shows internal parasite cases score the first in the study area (Appendix 7). The most probable reason for the more prevalence of abdominal pain and intestinal parasite may be the use of dirty water

due to scarcity that exposed them for water born diseases. Wound & infection and malaria treating plant species are taking second and third rank respectively.

The use of leaves accounts the highest percentage (40%) and followed by root (24%). This result may lead to the conclusion that harvesting medicinal plants is less destructive on the natural vegetation because the most frequently used part is the leaf. In other way it may also lead to the conclusion that harvesting of medicinal plants is likely, to be destructive because the second part used is root. As was stated by Dawit Abebe and Ahadu Ayehu (1993), those medicinal plants that are harvested for their roots, rhizomes, bulbs, bark, stem and whole part have severe effect on their survival. However, in the study area using roots might not be destructive for shrubs and trees because the traditional healers dig up small portion of the root from the root system.

The preference ranking result of the five plant species may show medicinal popularity of these plant species and probably the most efficacious at least in the context of the people who use them. The most preferred plants species were used to treat more than one health problem. *Acacia senegal* and *Aloe pirottae* for example threat 4 and 6 health problems respectively. The highest score for *Acacia senegal* while used to treat less number of health problems as compared to *Aloe sp.* may be due to its use to treat the most prevalent disease in the study area.

According to Debela Hunde *et al.,* (2004), lack of precission or specifying the dose in rough measurements is a major drawback of application of traditional medicinal plants. The study shows there is lack of precision of the dose in the study area. Specially, in relation to the root of administration where oral application was the lead, lack of precision can be the major drawback.

6.7.2.2. Livestock

A total of 20 plant species in to 19 genera and 14 families were recorded as ethnoveterinary use in the study area. Out of these 12 species were documented by Debela Hunde *et al.,* (2004). Still in the study area, many medicinal plants available to

use for the livestocks. The traditional system and religious beliefs may be restricted the information on livestock medicinal plants.

The most common disease is livestock wound. Plant species used to treat this disease are, *Abutilon fruticosum, Aloe pirottae Boscia minimifolia, Cissus rotundifolia, Commicarpus plumbagineus, Cucumis dipsaceus, Dodonaea angustifilia,* and *Ozoroa insignis.* The pastoralists are more knowledgeable than the settled agriculturalist in identifying livestock medicinal plant species, method of preparation and treatment.
The first route of application was external followed by oral. The study shows there is lack of precision of the dose. Most of the remedies were administered in higher quantities than that recommended for humans. Informants were explained the importance of care and proper handling in the preparation and dose of these traditional medicinal plants in order to treating livestocks rather than poisoning.

6.7.3. Forage

As was reported by informants the sanctuary is more suitable for camels than cattle. It was observed that camels constitute the highest proportion of the livestocks in the study area. This might be due to the composition of the forage species dominated by trees and shrubs (accounts 57.5%) which is more suitable for browsers. Based on their observation and perception on their livestock preference and palatability of feed *Balanites aegyptiaca, Balanites glabra, Opuntia ficus-indica, Acacia nilotica, Dichrostachis cinerea, Grewia, Plectranthus cylindraceus, Acacia albida, Acacia tortilis, Acacia etbaica, Cenchrus cilliaris, Eragrostis,* and *Panicum spp.* are considered and valued as the best-browsed and grazed species of the study area. Actually, the scale of preference depends on their availability and seasons, dry and wet.

In general, about 45% of the forage species are Fabaceae and Poaceae. This indicates the study area is much suitable for livestock browsing and grazing due to its high forage value. According to Alemayehu Mengistu (1998), the main problem of sustainable livestock production in Ethiopia is lack of sufficient nutrition. This might be the most probable reason for the highly utilization of the sanctuary by the pastoralists migrating

from the different part of the surrounding drylands. Unless there is an immediate system of management in this sanctuary, the size of the sanctuary is going shrinking from time to time. As was perceived by informants, the maximum pressure from the livestock, agricultural expansion, invasive species, fuel wood collection and charcoal making important forage trees, shrubs and grasses has significantly declining from time to time. There is a trend of increasing the density of unpalatable and less palatable species in the study area.

Plant species used for construction, craft and fuel

A total of 28 and 18 woody species are used for construction and fuel respectively. There is an overlap of plant species that are used for construction, craft and fuel (firewood and charcoal making). Almost all the plant species used for construction and craft are also used as source of fuel. Both the agriculturalists and pastoralists are depending on plant materials for the construction of their houses. However, the pastoralists are more efficient in the utilization of the plant material used for house construction. Once they prepare the full part of woody material used for the construction of the temporary huts they always move it from place to place using camels back rather than cutting new every time. This is a good practice as to the conservation point of view. Plant species like *Acacia albida, Acacia bussie, Acacia mellifera, Acacia seyal, Balanites aegyptiaca, Berchemia discolor, Dichristachys cinerea, Cordia africana, Cordia monoica* and *Terminalia brownii* are commonly used due to availability, strength, flexibility and resistance of termites for construction and crafts (Appendix 11).

Exploitation of trees for charcoal making and firewood is the common practice in the study area. Species like *Acacia albida, Acacia etbaica, Acacia nilotica, Acacia robusta, Balanites aegyptiaca, Balanites glabra, Berchemia discolor* and *Acacia tortilis* are more preferable for both firewood and charcoal making in the study area (Appendix 10). That is why these species are highly threatened in the BES. About 40% of the informants were stated *Lantana camara* as firewood. This might be a good practice to control the expansion of this invasive species which a silent killer of the natural vegetation.

6.7.4. Multipurpose woody species

Identification of multipurpose plant species is very important as to the conservation and management practice in the study area. The result from direct matrix ranking shows *Tamarindus indica* scores the first rank and followed by *Berchemia discolor* and *Balanites aegyptiaca*. These tree species were reported as multipurpose woody species in the different studies (Demel Teketay, 1995). As the result shows *Tamarindus indica* was given high score for market value and medicinal plant whereas, less score for firewood and charcoal. This is compatible with its population structure where the higher DBH classes are better than the lower DBH classes. In the case of *Berchemia discolor* the highest value is given for construction, firewood and charcoal making. Perhaps this attributed for the broken inverted J-shaped pattern in its population structure where the higher DBH classes can be exploited for these purposes. In addition, the second high value was given for forage that might be affected the lower DBH class (5-10 cm). *Acacia senegal* is the last and this might be the main reason for domination of *Acacia senegal* in the floristic composition of the Sanctuary in addition to environmental factors and biological factors like dispersal mechanism. In general, these plant species needs more attention for the sustainability of the sanctuary as to the elephant feed & local community.

6.7.4.1. Population structure of top ten multi-purpose woody plant species

Population structure has been used widely to examine the regeneration status of woody plants (Tamrat Bekele, 1994; Demel Teketay, 1997; Mekuria Argaw *et al.*, 1999).The over all patterns of population structure of the ten multipurpose woody species revealed healthy regeneration. However, the poor size distribution affinities observed may call for more serious and urgent attention to be given to the conservation of these woody species.

Out of the ten multipurpose woody species five of them have an inverted J-shaped pattern may show presence of recent recruitment in the lower size classes with a gradual decrease towards higher size classes and their reproductive capacity to sustain their species as far as proper management and conservation strategy will be designed for sustainability of the sanctuary. This kind of distribution normally indicates good regeneration (Mekuria

Argaw *et al.*, 1999), and regeneration status of the above species can be said to be normal.

Broken inverted J-shaped distribution for *Acacia etbaica* and *Berchemia discolor may* exhibit the exploitation of the small DBH class (5-10 cm) which may be used for making farm tools and house utensils, and the highest DBH classes for house construction & furniture, and firewood & charcoal making. *Berchemia discolor* has been reported to be rare from time to time elsewhere from East Africa to South Africa and Namibia, Madagascar and Arabia (Vollesen, 1989). In the BES this species is highly threatened due to its multipurpose function especially its highest value for construction, craft, charcoal making and firewood. Its "Oromiffaa" name known as "Jejeba" also indicates how it is very strong and important. Informants were explained their preference of *A. etbaica* for its flexibility to construct traditional pastoralist hats.

A U-shaped pattern of *Acacia robusta* and *Tamarindus indica* indicates selective cutting and removal of medium-sized trees. These two species are the highest both in height and DBH in the study area. Therefore, the local community may prefer the medium sized trees for various purposes and the smaller sized groups may be attributed to herbivory by both wildlife and livstocks.

A bell-shaped distribution pattern of *Balanites aegyptiaca* indicates its poor regeneration and fewer individuals at the higher DBH classes. Despite its multipurpose function and the most important browse species, *B. aegyptiaca* faces considerable threats worldwide and its population is declining (BIC, 2002). In the BES this species seems threatened too. The poor regeneration of this species may be due to the high utilization of its fruit both by human and animals, and the fewer individuals at the higher DBH class may be due to more cutting for charcoal making and fire wood, and construction. *B. aegyptiaca* is known for its value of provision of firewood and high quality charcoal (Sands, 1989).

6.8. Woody species browsed by elephants

Shrubs account 95.7% of the total density of the 24 woody species browsed by elephants where as trees only 4.3%. Since shrubs and climbers dominated the floristic composition of the sanctuary it may be the future challenge to support the highest feed demand of the elephants. Elephants are more prefer tree species for feed and spent most of the time in the woodlands and riverine forest. (Fig. 15).

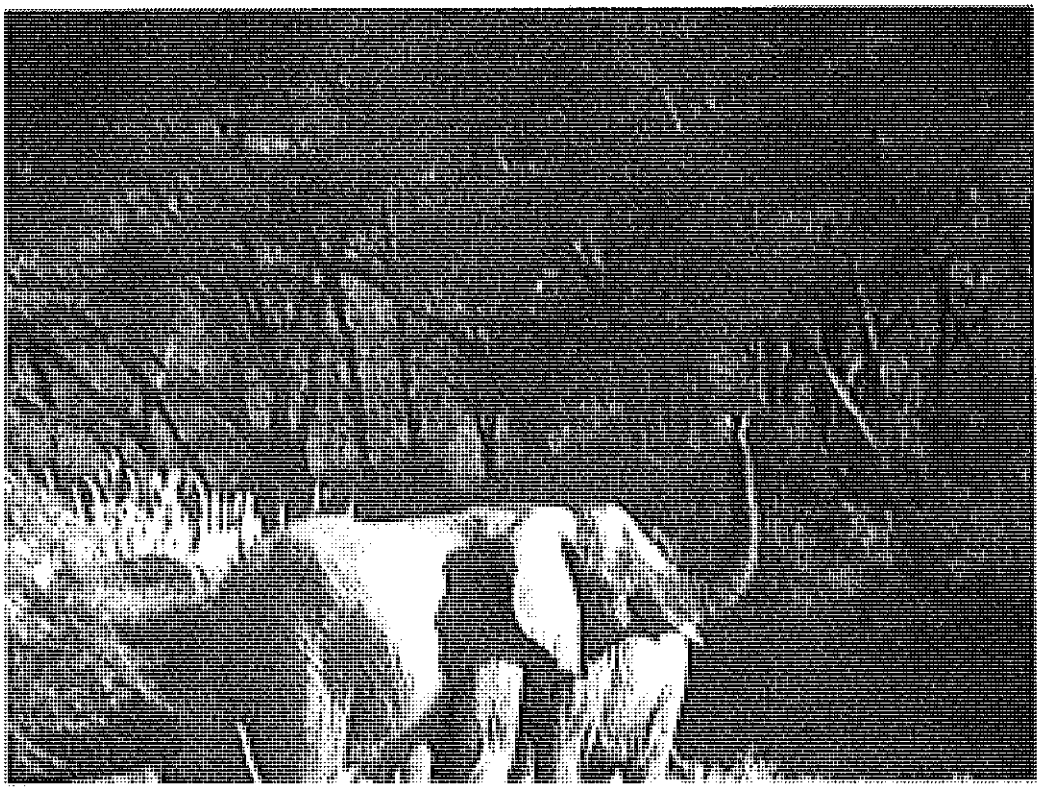


Fig. 15. Elephants browsing on the tree species (*Acacia robusta*).

6.8.1. Population structure of dominant woody species browsed by elephants

Out of the ten top browsed species by elephants, *Acacia tortilis, Acacia nilotica, Acacia etbaica, Balanites aegyptiaca, Balanites glabra, Berchemia discolor, Oncoba spinosa, Salvadora perisca and Tamarindus indica* are highly threatened and they account only 1.4% of the total density. The population structure of shrubs exhibited an inverted J-shaped frequency distribution indicating healthy regeneration. The tree species exhibited inverted J-shaped (*Opuntia ficus-indica, Acacia nilotica* and *Acacia tortilis*) indicating

healthy regeneration, broken inverted J-shaped *(Acacia etbaica, Balanites glabra* and *Berchemia discolor*) where fluctuation in the intermediate classes may indicate absence of regeneration at one particular time in the past, or selective removal of the trees by the local people, broken J-shaped (*Oncoba spinosa*) may indicat poor regeneration and selective romoval, U-shaped (*Acacia robusta, Salvadora perisca* and *Tamarindus indica*) may suggest absence of recruitment in the lower class and selective removal/exploitation of intermediate classes and bell-shaped (*Balanites aegyptiaca and Acacia albida*) frequency distribution which suggest absence or poor regeneration and recruitment in the lower class and selective removal/exploitation of the bigger DBH classes.

Even if the results of this study showed more destruction on the tree species, the resident elephants may not be claimed for this destruction because most of these woody species are multipurpose and highly utilized by people in the study area. According to Smallie and O'Connor (2000), very little destruction of vegetation was recorded by elephants in Venetia-Limpapo Natural Reserve in South Africa. Destruction of trees by elephants may occur sporadically, usually being a result of young bulls engaging in social displays (Guy, 1976).

6.8.2. Regeneration status of trees and shrubs browsed by elephants

The total regeneration of woody species in the BES shows shrubs and climbers dominated the regeneration. As stated by Mekuria Argaw *et al.,* (1999), in Ethiopia the uncontrolled removal of trees for various purposes is severely reducing the density of the species and affecting regeneration. The least regeneration count for tree species such as *Oncoba spinosa Acacia nilotica, Salvadora perisca, Acacia albida*, and *Acacia etbaica* could be due to the low density of mature trees in the standing vegetation or a poor seed dispersal strategy of the species. Top browsed trees like *Acacia robusta, Balanites aegyptiaca, B. glabra* and *Acacia tortilis* relativelly showed better regeneration might be attributed to its density of mature trees, presence of substantial amount of viable seeds in the soil and the wide dispersal of its seeds through ungulate faeces.

In the study area about 95% of the regeneration was recorded for shrubs and climbers. This result may show that the natural vegetation in the BES is moving towards shrubland/bushland since the population of trees is declining.

For species of *Opuntia ficus-indica, Opuntia stricta, Cryptostegia grandiflora, Euclea racemosa ssp. schimperi* and *Dodonaea angustifolia* regeneration status was not considered because some of these plant species are the most dominant in the study area and for some regeneration data was lacking.

6.9. The major anthropogenic impacts in the BES

Currently the natural vegetation of the BES is exploited in a destructive and unsustainable manner. The underlying root cause of deforestation and environmental degradation in the study area is an ever-increasing human population that caused influx of people from both high land and lawlands of the surrounding area. As a result of mass influx of a large number of farmers and their domestic stocks from the east and north, the home range of elephants of Babile has shrunk by about 65% since 1976 (Yirmed Demeke *et al.,* 2006). Therefore, the current area is estimated to be 35% of the original size during its establishment.

As stated by Feyera Senbeta and Fekadu Tefera (2001), protected areas have hardly been managed in Ethiopia due to population pressure. Even if the EWCO have an office in the Babile town to protect the BES, the human power, the logistics, and the system is not in a position to protect the sanctuary from destruction. The decisions made on the protected areas do not take due consideration of the interest of stakeholders, especially communities who are dependent on the local resources (Feyera Senbeta and Demel Teketay, 2003).

The achievements of protected area management systems may be difficult to assess in many developing countries, since there is at present no established system for monitoring trends in biodiversity changes (Danielsoen *et al.*, 2000). Due to this, the BES which is an important sanctuary for elephants is not legally gazetted and subsequently the protection

of the whole sanctuary will remain nominal as long as it is not legally gazetted. In addition, even if it could be gazetted, management plan that should carefully consider possibilities of sustainable utilization of the area by the local people should be considered. As stated by Feyera Senbeta and Demel Teketay (2003), lack of integration of the local people living around the conservation areas in the conservation efforts, and absence of law enforcement systems are the major constraints to the overall conservation efforts in Ethiopia.

Due to the agricultural potential of the area, especially along the Erer river, people coming from far area for shifting cultivation. Because of agricultural expansion along the Erer River an important multipurpose riverine trees such as *Acacia robusta, Tamarindus indica, Oncoba spinosa,* are declining from the area. In addition species of *Commiphora, Boswellia, Terminalia brownie, Berchemia discolor,* are highly declining from the woodland.

During the data collection period, it was observed that about 60% of the people doing farming in the sanctuary are coming from different areas even outside the Babile district. In general, temporary and permanent settlement, charcoal making, firewood collection, overgrazing, deliberate fire to clear land for agriculture, and selective tree cutting for construction are the main threats to biodiversity in the sanctuary. As stated by Yirmed Demeke *et al.*, 2006), on average 991.5 sacks of charcoal, 843 bundles of firewood and 800 bundles of house construction materials are exploited per month from the BES.

Invasive species such as *Lantana camara* and *Parthenium hystrophorus* are the other threat for the sanctuary. The significant number of regeneration recorded for *L. camara* shows the severity of invasion in the sanctuary. In the plots, where maximum number of *L.camara* was recorded in community 1, the species richness was only 21, this clearly shows the dominant nature of this species over the rest. If this trend continues *L. camara* will be a silent killer of the natural vegetation in the BES. The Northern or upper part of the Erer valley is completely covered by *L. camara* in all land features i.e. the riverbanks, field plains, and hillsides areas (personal observation). Perhaps the invasion could be fast

since the drainage pattern is from North to South direction in the sanctuary. Unless attention is given to the expansion of *L. camara*, it will dominate the vegetation in the study area.

The local communities have a practice of cutting *L. camara* from the base before it flowers and burning it on site afterwards. This shows how the local communities understood the impact of *L. camara* and the way to reduce its impact in the study area. Further more, *L. camara* is one of the most prevalent and noxious weeds causing hepatotoxicity in grazing animals such as cow, buffaloes, sheep and goats (Sharma *et al.*, 1988; Sharma and Makkar, 1981). *L. camara* poisoning causes obstructive jaundice and within a few hours of browsing upon its foliage, animals go off-feed and become severely constipated within 48 h (Sharma *et al.*, 1989).

7. Conclusion and recommendations

The floristic composition in the Babile elephant sanctuary revealed that there is high species diversity and better woody species density even if the highest proportion of the density is accounted for shrubs and climbers regardless of the effect of anthropogenic factors. Shrubs were found to be more dominant than trees and no wooded grassland was documented in the study area. The floristic list and the community analysis showed the vegetation of the area belongs to *Acacia-Commiphora* deciduous bushland and thicket, *Acacia-Commiphora –Terminalia* woodland, and riverine forest vegetations in its diverse nature over short distance

More number of plant species are used for food and forage. In addition, medicinal plants play a very crucial role in the provision of primary health care for the most prevalent diseases among the farmers and pastoralists as well as for their livestocks.

It is also the shelter for many plant species in which the local communities make use for fuel, construction, household utilities, market value, flavoring, cleansing, farm tools, honey collection, and traditional uses. In its totality, BES is a reserve of wealth. It has a great potential of multipurpose woody plant species such as *Acacia senegal, Tamarindus*

indica, Opuntia ficus-indica, Acacia robusta, Balanites aeygptiaca, Berchemia discolor, Acacia bussei, Acacia tortilis, Acacia etbaica and Commiphora erythraea where most of them highly threatened.

The area is able to attract eco-tourism due to its biodiversity potential and topographic features. This can generate income that can be used to the benefits of the sanctuary and the local community if better management for the sanctuary is in plan. Due to the accessibility of this particular habitat, it can be used as an outdoor classroom and research site.

However, uncontrolled agricultural expansion, human settlement, excessive tree cutting and over grazing could lead to an irreversible change in the function of this natural vegetation. These are the serious impacts that affected community **1** and **2** which are from the riverine forest. The destruction of the vegetation could be one of the reasons why the Erer river that changed from perennial in the past to seasonal river at present. The other contributing factors could be the destruction and clearing of the natural vegetation in the mountains in the Harerge highlands, which are the source of water for rivers like Erer and Gobelle. This was forecasted by Demel Teketay (1996) who stated that, the rivers Erer and Gobelle would dry up if water on the mountains could not retained. The current condition of all the rivers flowing into the sanctuary is very bad. The rivers dry up soon after the rains (were perennial before). Undoubtedly, the loss of vegetation cover has a contribution. This inturn will reduce drinking water supplies and disrupt irrigation schemes which are so vital in the lowlands including the Ogaden area since these rivers are tributaries of Wabishebele River. Thus, the riverine vegetation needs immediate conservation and rehabilitation measure due to its far-reaching impact.

Moreover, invasive speciessuch as *Lantana camara* and *Parthenium hystrophorus* are the other threat for the sanctuary. Therefore, management action should be develop to reverse or at least stabilize the present trend in the sanctuary. This could be achieved by appropriate management and use plans that include restoration and rehabilitation measures. In addition, for restoration/rehabilitation and proper management of these area, soil analysis, soil seed bank study, phenology, and seed ecology (seed production,

dispersal, germination and predation) are required. Since restoration of the vegetation is only possible through natural regeneration, knowledge on the composition and density of the soil seed bank, status and pattern of seedling recruitment, population distribution and species representation (composition) is very important. Restoration could be achieved through artificial methods such as direct sowing, enrichment planting and direct planting (Karin and Hakan, 1992). Therefore, knowledge of the germination requirements of the important tree species is essential.

In general, as part of the s remaining vegetation cover in the Babile Elephant Sanctuary and as part of the habitat of the only living representative individuals of the elephant (*Loxodonta africana orleansi*) as well as a variety of other animals and to the benefit of the local community, the Babile Elephant Sanctuary should be afforded the highest protection possible as a matter of urgency before it is too late.

Recommendations

- Rehabilitation by plantation especially the indigenous multipurpose tree species that are highly threatened but already exist in the valley should be given emphasis. This can be done by organizing the local communities, NGOs like Menschen fur Menschen (MfM), CARE who are actively working in that locality.
- Demarcating (gazzeting) the sanctuary for proper management.
- To establish a system of enclosure in the different seasons in the different parts of the sanctuary to give ample time for regeneration.
- To establish a mechanism to control or reduce the fast expansion rate of invasive species like *Lantana camara* in the upper part of the sanctuary.
- To benefit the local community so that this develop an interest of protectind and maintaining the sanctuary.
- Low enforcement measure to control illegal agricultural activity.
- To control people coming from far area even from the highland for extra agricultural activity and charcoal making assuming that it is no ones land. Many people interviewed in the study area assume that the sanctuary is no ones

property and free to utilize for every thing. This needs public awareness activity as to the sanctuary and its benefit to the country as well as the local community.

- Build the capacity of the BES office in terms of human power, logistics and good management system and establish a new scout camp inside the sanctuary.
- Upgrade the road towards the sanctuary and promotion work for eco-tourism.
- Further ecological studies are needed like the soil seed bank & seed ecology of the most important tree species, and soil analysis.
- Investigate other potentials of biodiversity such as mammals, reptiles, birds (It is one of an important bird areas in the country).
- The clan leaders and older members who are respected by the local communities have positive outlooks on the importance of the sanctuary. They strongly believe with the survival of the elephants in that environment. So this needs further sociological investigation to integrate indigenous knowledge based management practice.
- Sociological study to investigate the source of conflict between agriculturalists and pastoralists in the sanctuary needs to be carried out and this could provide base line information to help develop proper management and conservation plan.
- The pattern and proportion of trees and shrubs utilization by elephants need to be investigated.
- Conduct socio-economic study and look an alternative means of subsistence for those local communities dependent on charcoal making and illegal settlers in the sanctuary.

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10. Appendeces

Appendix 1: Species list of the study area.

(pe-H = perennial herb; An-H = annual herb; Sh = shrub; T = tree; Cl = climber; An-g = annual grass; pe-g = perennial grass)

Coll .No.	Scientific name	Family	Habit	Vernacular name
44	*Abutilon bidentatum* (Hochst.) A. Rich.	Malvaceae	Pe-H,	
197	*Abutilon fruticosum* Guill. & Perr.	Malvaceae	Sh	Balanbal (S)
241	*Acacia albida* Del.	Fabaceae	T	Gerbii
5	*Acacia brevispica* Harms	Fabaceae	Sh	Hammareeysa (Or)
2	*Acacia bussei* Harms ex Sjostedt	Fabaceae	T	Hallo (Or)
185	*Acacia etbaica* Schweinf.	Fabaceae	T	Dodoti (Or)
36	*Acacia mellifera* (Vahl) Benth.	Fabaceae	Sh/T	Bilaila (Or)
130	*Acacia nilotica* (L.) Willd. ex Del.	Fabaceae	T	Serkema (Or)
113	*Acacia oerfota* (Forssk.) Schweinf.	Fabaceae	Sh	Ajoo (Or)
17	*Acacia robusta* Burch.	Fabaceae	T	Wangeyo (Or)
1	*Acacia senegal* (L.) Willd.	Fabaceae	Sh	Sobensa (Or)
243	*Acacia seyal* Del.	Fabaceae	T	Waccuu (Or)
34	*Acacia tortilis* (Forssk.) Hayne	Fabaceae	T	Dhedacha (Or)
3	*Acalypha fruticosa* Forssk.	Euphorbiaceae	Sh	Dhirii (Or)
45	*Achyranthes aspera* L.	Amaranthaceae	H	
109	*Acokanthera schimperi* (A. DC.) Schweinf.	Apocynaceae	Sh/T	
144	*Actinopteris dimorpha* Pic. Serm.	Actinopteridaceae	Fern	
149	*Adiantum capillus-veneris* L.	Adiantaceae	Fern	
38	*Agava sisalana* Perrine ex Engl.	Agavaceae	Sh	Algee (Or)
169	*Albuca abyssinica* Jacq.	Hyacinthaceae	H	
100	*Allophylus rubifolius* (A. Rich.) Engl.	Sapindaceae	Sh/T	
68	*Aloe pirottae* Berger	Aloaceae	H	Hargeessa (Or)
105	*Amaranthus caudatus* L.	Amaranthaceae	H	
111	*Amaranthus palmeri* S. Wats.	Amaranthaceae	H	
74	*Aristida adscensionis* L.	Poaceae	An-g	

123	*Asparagus leptocladodius* Chiov.	Asparagaceae	Sh	Keleme sere (Or)
115	*Balanites aegyptiaca* (L.) Del.	Balanitaceae	T	Bedeno (Or)
116	*Balanites glabra* Mildbr. & Schlecht.	Balanitaceae	T	Kutka (S)
84	*Barleria eranthemoides* R. Br. ex C.B. Clarke	Acanthaceae	Sh	Goda-adosha (S) Kumutu gala (Or)
267	*Barleria parviflora* R. Br. ex T. Anders.	Acanthaceae	Sh	Nagadh (S)
127	*Berchemia discolor* (Klotzsch) Hemsl.	Rhamnaceae	T	Jejeba (Or),dheen (S)
87	*Bidens biternata* (Laur.) Merr. & Sherff	Asteraceae	H	
69	*Blepharis edulis* (Forssk.) Pers.	Acanthaceae	H	Kumutu gala (Or)
53	*Blepharis maderaspatensis* (L.) Roth	Acanthaceae	H	
276	*Boscia minimifolia* Chiov.	Capparidaceae	T	Meygag (S)
134	*Boswellia neglecta* S. Moore	Burseraceae	T	Muka libaneta (Or)
210	*Buckollia volubilis* (Schltr.) Venter & R. L. Verh.	Asclepiadaceae	Cl	Hida gagura (Or)
278	*Cadaba farinosa* Forssk.	Capparidaceae	Sh	Kelkelcha (Or) , Kaligii jogg (S)
237	*Calotropis procera* (Ait.) Ait. f.	Asclepiadaceae	Sh	
262	*Canthium setiflorum* Hiern	Rubiaceae	Sh	
196	*Capparis fascicularis* DC.	Capparidaceae	Cl	Hida sere (Or)
247	*Capparis sepiaria* L.	Capparidaceae	Sh	Riga gange (Or)
112	*Capparis tomentosa* Lam.	Capparidaceae	Sh	Gemora (Or)
	Caralluma priogonium K. Schum.	Asclepiadaceae	H	
199	*Caralluma speciosa* (N.E.Br.) N.E.Br	Asclepiadaceae	H	Ya'ii beraa (Or)
164	*Cardiospermum halicacabum* L.	Sapindaceae	H	
226	*Carissa spinarum* L.	Apocynaceae	Sh	Agemsa (Or)
124	*Caucanthus auriculatus* (Radlk.) Niedenzu	Malpighiaceae	Cl	Galle addi (Or)
67	*Cenchrus ciliaris* L.	Poaceae	Pe-g	Burkaa lenchoo (Or), Gaaroolee (S)
108	*Centella asiatica* (L.) Urban	Apiaceae	H	
70	*Chamaecrista mimosoides* (L.) Greene	Fabaceae	H	
212	*Chamaecrista nigricans* (Vahl) Greene	Fabaceae	H	

227	*Chenopodium album* L.	Chenopodiaceae	H	
76	*Chionothrix latifolia* Rendle	Amaranthaceae	Sh	Ged-ad (S). Kel adi (Or)
165	*Chloris pycnothrix* Trin.	Poaceae	An-g	
33	*Chloris virgata* Sw.	Poaceae	An-g	Meta leme (Or),
96	*Cissus rotundifolia* (Forssk.) Vahl	Vitaceae	Cl	Shumbur lubu (Or)
163	*Cleome monophylla* L.	Capparidaceae	H	
235	*Combretum molle* R. Br. ex G. Don	Combretaceae	T	Obelbiyodka (S)
15	*Commelina stephaniniana* Chiov.	Commelinaceae	H	Holaa gebis (Or)
219	*Commicarpus plumbagineus* (Cav.) Standl.	Nyctaginaceae	Cl	Kontom adi (Or)
121	*Commicarpus sinuatus* Meikle	Nyctaginaceae	Cl	Kontom dima (Or)
261	*Commiphora erythraea* (Ehrenb.) Engl.	Burseraceae	T	Kedhon (S)
133	*Commiphora schimperi* (Berg) Engl.	Burseraceae	T	
172	*Convolvulus siculus* L.	Convolvulaceae	H	
139	*Corchorus tridens* L.	Tiliaceae	H	
40	*Corchorus trilocularis* L.	Tiliaceae	H	
258	*Cordia gharaf* Aschers	Boraginaceae	T	Medher (S)
201	*Cordia monoica* Roxb.	Boraginaceae	T	Medhero (Or)
194	*Cordia ovalis* R.Br	Boraginaceae	T	Medhero (Or)
145	*Crabbea volutina* S. Moore	Acanthaceae	H	
180	*Crinum abyssinicum* Hochst. ex. A. Rich.	Amaryllidaceae	H-bulb	
102	*Crotalaria laburnifolia* L.	Fabaceae	Sh	
263	*Crotalaria plowdenii* Bak.	Fabaceae	H	
230	*Crotalaria pycnostachya* Benth.	Fabaceae	H	Dharjo (S)
16	*Crotalaria quartiniana* A. Rich.	Fabaceae	Cl	
284	*Croton dichogamus* Pax.	Euphorbiaceae	Sh	Bal-add (S)
11	*Cryptostegia grandiflora* Roxb. ex R. Br.	Asclepiadaceae	Cl	Huda-dhukal (S) Hida gagura (Or)
55	*Cucumis dipsaceus* Ehrenb. ex Spach	Cucurbitaceae	H	Harre goggee (Or)
225	*Cyathula orthacantha* (Asch.) Schinz	Amaranthaceae	H	Kore werabeysaa(Or)
202	*Cynodon dactylon* (L.) Pers.	Poaceae	An-g	

104	*Cyperus rigidifolius* Steud.	Cyperaceae	H	
288	*Cyphostemma adenocaule* (Steud. ex A. Rich.) Descoings ex Wild & Drummond	Vitaceae	Cl	Armoo (Or)
32	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae	An-g	Migiira haaree (Or)
117	*Dichrostachys cinerea* (L.) Wight & Arn.	Fabaceae	Sh	Jirme (Or)
140	*Dicliptera verticillata* (Forssk.) C. Chr.	Acanthaceae	H	
118	*Dicoma tomentosa* Cass.	Asteraceae	H	
63	*Digitaria ternate* (A. Rich.) Stapf	Poaceae	An-g	
260	*Dodonaea angustifolia* L. f.	Sapindaceae	Sh	Edecha (Or)
256	*Dolichos trilobus* L.	Fabaceae	H	
277	*Drimia altissima* (L.f.) Ker. Gawl.	Hyacinthaceae	H	Geel-adheey (S)
146	*Enteropogon macrostachyus* (Hochst ex A. Rich.) Benth.	Poaceae	Pr/g	Oleesiin (Or)
42	*Eragrostis aspera* (Jacq.) Nees	Poaceae	An-g	Citaa teyroo (Or)
157	*Eragrostis lepida* (A. Rich.) Hochst. ex Steud.	Poaceae	An-g	
239	*Eragrostis papposa* (Roem. & Schult.) Steud	Poaceae	Pr-g	
259	*Euclea racemosa* Murr. ssp. *schimperi* A. DC	Ebenaceae	Sh	Mieysa (Or)
114	*Euphorbia abyssinica* Gmel.	Euphorbiaceae	T	Dharkeena (Or)
10	*Euphorbia cryptospinosa* Bally.	Euphorbiaceae	Sh	
188	*Euphorbia inaequilatera* Sond.	Euphorbiaceae	H	
57	*Euphorbia burgeri* M. Gilbert	Euphorbiaceae	Sh	Hadami (Or)
167	*Evolvulus alsinoides* (L.) L.	Convolvulaceae	H	
234	*Ficus vallis-choudae* Del.	Moraceae	T	Oda (Or)
83	*Ficus vasta* Forssk.	Moraceae	T	Kilxxu (Or)
150	*Fimbristylis dichotoma* (L.) Vahl	Cyperaceae	H	
206	*Flueggea virosa* (Willd.) Voight	Euphorbiaceae	Sh	Kechachile (Or)
216	*Gomphrena celosioides* Mart.	Amaranthaceae	H	
6	*Grewia bicolor* Juss.	Tiliaceae	Sh	Suta nekebu (Or)
35	*Grewia erythraea* Schweinf.	Tiliaceae	Sh	Dheekaa (Or)

37	*Grewia ferruginea* Hochst. ex A. Rich.	Tiliaceae	Sh	Ogemdi guraatii (Or)
186	*Grewia flavescens* Juss.	Tiliaceae	Cl/Sh	Tateysa (Or)
	Grewia kakothamnos K. Schum.	Tiliaceae	Sh	Midhayoo (S)
30	*Grewia pennicillata* Chiov.	Tiliaceae	Sh	.
257	*Grewia schweinfurthii* Burret	Tiliaceae	Sh	Midha gure (Or), midha medew (S)
166	*Grewia tenax* (Forssk.) Fiori	Tiliaceae	Sh	Dheferur (S)
198	*Grewia villosa* Willd.	Tiliaceae	Sh	Ogemdi adii (Or)
248	*Gutenbergia rueppelli* Sch. Bip.	Asteraceae	H	
91	*Heliotropium aegyptiacum* Lehm.	Boraginaceae	H	Madariis (S)
265	*Heliotropium rariflorum* Stocks	Boraginaceae	H	
92	*Hetropogon contortus* (L.) Roem. & Schult.	Poaceae	Pr-g	
49	*Hibiscus dongolensis* Del.	Malvaceae	Sh/H	
173	*Hibiscus ludwigii* Eckl. & Zeyh.	Malvaceae	Sh	
23	*Hibiscus micranthus* L. f.	Malvaceae	H	
175	*Hibiscus ovalifolius* (Forssk.) Vahl	Malvaceae	Sh	
137	*Hybanthus enneaspermus* (L.) F. Muell.	Violaceae	H	
240	*Indigofera amorphoides* Jaub. & Spach	Fabaceae	H	Jeere (S)
255	*Indigofera brevicalyx* Bak.	Fabaceae	H	
174	*Indigofera coerulea* Roxb.	Fabaceae	H	
56	*Indigofera hochstetteri* Bak.	Fabaceae	H	Sogida re'ee (Or)
103	*Indigofera parviflora* Heyne ex Wight & Arn.	Fabaceae	H	
14	*Ipomea obscura* (L.) Ker-Gawl.	Convolvulaceae	H	Aneysu (Or)
282	*Ipomoea cicatricosa* Bak.	Convolvulaceae	Sh	Weeyla-wa (S)
	Ipomoea hildebrandtii Vatke ssp. *Megaensis* Verdc.	Convolvulaceae	Pe-H	
236	*Ipomoea hochstetteri* House	Convolvulaceae	H	Shenferol (S), kuba shenii (Or)
214	*Ipomoea polymorpha* Roem. & Schult.	Convolvulaceae	H	
286	*Jasminum grandiflorum* L. ssp.	Oleaceae	Cl	Biluu (Or)

	floribundum R. Br. ex Fresen.			
147	*Jasminum schimperi* Vatke	Oleaceae	Cl	
183	*Justcia schimperiana* (Hochest. ex Nees) J. Andes	Acanthaceae	Sh	Dhumuga (Or)
120	*Justicia diclipteroides* Lindau	Acanthaceae	H	
25	*Justicia flava* (Vahl.) Vahl.	Acanthaceae	H	
22	*Kalanchoe lanceolata* (Forssk.) Pers.	Crassulaceae	H	
31	*Kalanchoe lanciniata* (L.) DC.	Crassulaceae	H	
58	*Kleinia grantii* (Oliv. & Hiern) Hook. f.	Asteraceae	H	
217	*Kleinia odora* (Forssk.) DC.	Asteraceae	Sh	Luko (Or)
195	*Kleinia pendula* (Forssk.) DC.	Asteraceae	H	
9	*Kleinia squarrosa* Cufod.	Asteraceae	Sh	Luko(Or)
264	*Kohautia caespitosa* Schnizl.	Rubiaceae	H	
273	*Lannea triphylla* (A. Rich.) Engl.	Anacardiaceae	Sh / T	Nuk (S)
73	*Lantana camara* (L.)	Verbenaceae	Sh	Beke arkete (Or)
177	*Lantana viburnoides* (Forssk) Vahl	Verbenaceae	Sh	
231	*Lepidagathis calycina* Hochst. ex Nees	Acanthaceae	Sh	Echini dido (Or)
189	*Lepidagathis aristata* (Vahl) Nees	Acanthaceae	H	Belan-bel (S)
242	*Leucas abyssinica* (Benth.) Briq.var. *brachycalyx* (Chiov.) Lanza.	Lamiaceae	Sh	
21	*Leucas martinicensis* (Jacq.) R. Br.	Lamiaceae	H	Dunfure (Or)
148	*Melhania ovata* (Cav.) Spreng.	Stercullariaceae	H	
221	*Melhania velutina* Forssk.	Stercullariaceae	Pe-H	
151	*Melinis repens* (Willd.) Zizka	Poaceae	An-g	
52	*Monechma debile* (Forssk.) Nees	Acanthaceae	H	
95	*Ocimum forskolei* Benth.	Lamiaceae	H	Rahana besho (Or)
238	*Ocimum lamiifolium* Hochst. ex. Benth.	Lamiaceae	H	
266	*Ocimum spicatum* Defl.	Lamiaceae	H	
107	*Ocimum gratissimum* L.	Lamiaceae	H	
244	*Oncoba spinosa* Forssk.	Flacourtiaceae	T	Jilbo (Or)

8	*Opuntia ficus-indica* (L.) Miller	Cactaceae	Sh/T	Tini (Or)
7	*Opuntia stricta* (Haworth) Haworth	Cactaceae	Sh	Kenchere (Or)
143	*Oxygonum sinuatum* (Meisn.) Dammer	Polygonaceae	H	
209	*Ozoroa insignis* Del.	Anacardiaceae	T	
80	*Panicum maximum* Jacq.	poaceae	Pr-g	Citaa arbii (Or), muressa (Or)
46	*Panicum monticola* Hook. f	Poaceae	An-g	
24	*Panicum repens* L.	Poaceae	An-g	
274	*Pappea capensis* Eckl. & Zeyh.	Sapindaceae	T	Biqee (Or)
106	*Paracalyx somalorum* (Vierh.) Ali	Fabaceae	Cl	
77	*Parthenium hysterophorus* L.	Asteraceae	H	Dhimbil (Or)
204	*Pavetta gardeniifolia* A. Rich.	Rubiaceae	Sh	
249	*Pavonia arabica* Hochst. & Steud. ex Boiss.	Malvaceae	H	
141	*Pavonia triloba* Guill. & Perr.	Malvaceae	H	
155	*Pavonia urens* Cav.	Malvaceae	H	
142	*Pavonia zeylanica* Cav.	Malvaceae	H	
253	*Pegolettia senegalensis* Cass.	Asteraceae	H	
268	*Pelargonium erlangerianum* Knuth.	Geraniaceae	H	
51	*Pentarrhinum somaliense* (N. E. Br.) Liede	Asclepiadaceae	Cl	
65	*Periploca linearifolia* A. Rich. & Quart. - Dill.	Asclepiadaceae	Cl	Jima bero (Or); Meranka (S)
72	*Peristrophe paniculata* (Forssk.)Brummitt	Acanthaceae	H	
154	*Perotis patens* Gand.	Poaceae	An-g	
79	*Phyllanthus maderaspatensis* L.	Euphorbiaceae	H	
97	*Phyllanthus rotundifolius* Willd.	Euphorbiaceae	H	
136	*Picris abyssinica* Sch. Bip.	Asteraceae	H	
89	*Plectranthus cylindraceus* Hochst. ex Benth.	Lamiaceae	H	
60	*Plectranthus puberulentus* J.K Morton	Lamiaceae	Sh	
152	*Plectranthus rupestris* (Hochst.) Benth.	Lamiaceae	H	
28	*Plectranthus barbatus* Benth.	Lamiaceae	H	
184	*Plicosepalus curviflorus* (Oliv.) Tieghem	Loranthaceae	ep	
50	*Plumbago zeylanica* L.	Plumbaginaceae	H	

193	*Polygala sphenoptera* Fresen.	Polygalaceae	H	
251	*Premna oligotricha* Bak.	Verbenaceae	Sh	Jac-jacle (S)
191	*Prosopis juliflora* (Sw.) DC.	Fabaceae	Sh	Ged-adab (S)
98	*Rhus natalensis* Krauss	Anacardiaceae	Sh	Dobobeeysaa (Or)
223	*Rhynchosia minima* (L.) DC.	Fabaceae	H	
19	*Ruellia patula* Jacq.	Acanthaceae	H	Dhekdhek (Or)
74	*Salvadora persica* L.	Salvadoraceae	T	Ade (S)
90	*Sansevieria abyssinica* N.E. Br.	Dracaenaceae	Sh	
41	*Sarcostemma viminale* (L.)R.Br	Asclepiadaceae	Cl	
71	*Seddera arabica* (Forssk.) Choisy	Convolvulaceae	H	
233	*Seddera hallieri* Engl. & Pilg.	Convolvolaceae	H	Alati jole (Or)
168	*Senna italica* Mill.	Fabaceae	H	
101	*Senna obtusifolia* (L.) Irwin & Barneby	Fabaceae	Sh	
300	*Senna singueana* (Del.) Lock	Fabaceae	Sh	
43	*Setaria verticillata* (L.) P. Beauv.	Poaceae	An-g	Mara-boob (S)
82	*Solanecio angulatus* (Vahl.) C. Jeffrey	Asteraceae	Cl	
222	*Solanum glabratum* Dunal	Solanaceae	H	
18	*Solanum incanum* L.	Solanaceae	Sh	Hidi (Or)
48	*Solanum nigrum* L.	Solanaceae	H	Kiriir (S)
203	*Spermacoce senesis* (Klotzsch) Hiern	Rubiaceae	H	
132	*Steganotaenia araliacea* Hochst.	Apiaceae	T	
62	*Sterculia africana* (Lour.) Fiori	Sterculiaceae	T	Geri (Or)
250	*Stylosanthes fruticosa* (Retz.) Alston	Fabaceae	Pe-H	
129	*Tagetes minuta* L.	Asteraceae	H	
228	*Tamarindus indica* L.	Fabaceae	T	Roka (Or)
252	*Tephrosia pumila* (Lam.) Pers.	Fabaceae	H	
131	*Terminalia brownii* Fresen.	Combretaceae	T	Bireysaa (Or)
27	*Tetrapogon cenchriformis* (A. Rich.) Clayton	Poaceae	An-g	Remshii (Or)
270	*Trichilia emetica* Vahl	Meliaceae	T	Ununuu (Or)

153	*Tragia pungens* (Forssk) Muell.Arg.	Euphorbiaceae	H	Dobi (Or)
170	*Tribulus cistoides* L.	Zygophyllaceae	H	
26	*Trichodesma zeylanicum* (L.) R.Br.	Boraginaceae	H	
29	*Triumfetta heterocarpa* Sprague & Hutch.	Tiliaceae	Sh	
208	*Tylosema fassoglensis* (Kotschy ex Schweinf.) Torre & Hillc.	Fabaceae	Cl	
110	*Typha elephantina* Roxb.	Typhaceae		
85	*Vepris glomerata* (F. Haffm.)	Rutaceae	Sh	
88	*Vernonia cinerascens* Sch. Bip.	Asteraceae	Sh	Hiil (S)
66	*Vigna membranacea* A. Rich.	Fabaceae	H	
287	*Withania somnifera* (L.) Dun. In DC.	Solanaceae	H	Hidi gude-ye (Or), Guryo-fan (S)
126	*Xanthium strumarium* L.	Asteraceae	H	Karis budeey (S)
280	*Ximenia caffra* Sond.	Olacaceae	Sh	Hudha jeldo (Or)
156	*Zanthozylum chalybeum* Engl.	Rutaceae	T	
83	*Zinnia peruviana* (L.) L.	Asteraceae	H	
178	*Ziziphus spina-christi* (L.) Desf.	Rhamnaceae	T	Kurkura,geb (S)
211	*Zornia glochidiata* Reichb. ex DC.	Fabaceae	H	

Appendix 2. List of families with the corresponding number of species.

Family	**No.of species**	**Percentage**
Fabaceae	36	15.1
Poaceae	19	8.0
Asteraceae	15	6.3
Acanthaceae	14	5.9
Tiliaceae	12	5.0
Euphorbiaceae	10	4.2
Lamiaceae	10	4.2
Malvaceae	10	4.2
Convolvulaceae	9	3.8
Asclepiadaceae	8	3.4
Amaranthaceae	6	2.5
Boraginaceae	6	2.5
Capparidaceae	6	2.5
Rubiaceae	4	1.7

Sapindaceae	4	1.7
Solanaceae	4	1.7
Verbenaceae	3	1.3
Anacardiaceae	3	1.3
Burseraceae	3	1.3
Sterculiaceae	3	1.3
Apiaceae	2	0.8
Apocynaceae	2	0.8
Balanitaceae	2	0.8
Cactaceae	2	0.8
Combretaceae	2	0.8
Crassulaceae	2	0.8
Cyperaceae	2	0.8
Hyacinthaceae	2	0.8
Moraceae	2	0.8
Nyctaginaceae	2	0.8
Oleaceae	2	0.8
Polygonaceae	2	0.8
Rhamnaceae	2	0.8
Rutaceae	2	0.8
Vitaceae	2	0.8
Actinopteridaceae	1	0.4
Adiantaceae	1	0.4
Agavaceae	1	0.4
Aloaceae	1	0.4
Amaryllidaceae	1	0.4
Asparagaceae	1	0.4
Chenopodiaceae	1	0.4
Commelinaceae	1	0.4
Cucurbitaceae	1	0.4
Dracaenaceae	1	0.4
Ebenaceae	1	0.4
Flacourtiaceae	1	0.4
Geraniaceae	1	0.4
Loranthaceae	1	0.4
Malpighiaceae	1	0.4
Meliaceae	1	0.4
Olacaceae	1	0.4
Plumbaginaceae	1	0.4
Salvadoraceae	1	0.4
Typhaceae	1	0.4
Violaceae	1	0.4
Zygophyllaceae	1	0.4

Appendix 3. Distribution of sample sites in the study area.

No.	Site name	GPS reading	Altitude	Land form	Surface feature	Vegetation type	No. of quadrats	Remark
1	Horo roba	09°06'46"N 42°15'58"E	1250m	River plain	Fine sand & loam soil	Riverine forest	5	Agricultural expansion
2	Raree Senjir	09°02'30"N 42°16'36"E	1232m	River plain	Fine sand & loam soil	Riverine forest	5	Livestocks & settlement
3	Walbi	09°00'16"N 42°16'44"E	1225m	River plain	Fine sand & loam soil	Riverine forest	5	Elephants usual area
4	Gende Abdi(Northern part)	09°09'21"N 42°15'43"E	1242m	Plain	sandy	woodland	6	High tree cutting
5	Lefaa Waataa (Eastern part)	09°06'15"N 42°16'09"E	1245m	Plain	sandy	Bushland & thichet	7	Over browsing
6	Raree Adem	09°04'30"N 42°29'16"E	1280m	Plain	sandy	Scattered bushland	4	"
7	Shek Dheera	09°04'58"N 42°17'07"E	1266m	Plain & hillside bottom	Rocky	Shrubby	4	"
8	GaaraaBocisoo(East of Erer River)	09°08'97"N 42°16'87"E	4322-4720f	Hillside	Rocky	Bushland/ scrub	6	"
9	Subaan alah (East of Erer River)	09°06'73"N 42°16'67"E	4110-4600f	Mt. bottom	Rocky	woodland	4	Tree cutting
10	Kiltu gudaal	09°07'25"N 42°15'44"E	4180f	Flat plain	Sand & small stones	woodland	10	"
11	Kurfaa dhirii (West of river erer)	09°03'34"N 42°16'11"E	1228m	Undulating hills	Sandy & rocky	woodland	9	"
12	Kurfaa keraa (Weat of Erer river)	09°03'25"N 42°15'39"E	1260-1310m	Hill side	Rocky	woodland	10	"

Appendix 4. Table for importance Value Index (IVI) of woody species.

Scientif name	Habit	freq	Dens/ha	BA m^2/ha	Rfre	Rden	Rdom	IVI
Acacia robusta	T	15	100.7	7.006	1.300	0.39	39.3	41.0
Opuntia stricta	Sh	57	3842.7	0.963	4.939	26.50	5.4	36.8
Acacia senegal	Sh	52	2522.7	0.191	4.506	9.77	1.1	15.3
Acacia brevispica	Sh	59	2261.3	0.180	5.113	8.76	1.0	14.9
Tamarindus indica	T	5	15.7	2.462	0.433	0.06	13.8	14.3
Opuntia ficus-indica	T	50	216.7	1.130	4.333	0.84	6.3	11.5
Acacia mellifera	Sh	50	1274.7	0.260	4.333	4.94	1.5	10.7
Euphorbia burgeri	Sh	36	1664.0	0.191	3.120	6.44	1.1	10.6
Acacia bussei	T	40	47.3	0.917	3.466	0.18	5.2	8.8
Cissus rotundifolia	Cl	49	1034.7	0.012	4.246	4.01	0.1	8.3
Grewia tenax	Sh	35	1082.7	0.112	3.033	4.19	0.6	7.9
Acacia tortilis	T	36	41.3	0.702	3.120	0.16	3.9	7.2
Terminalia brownii	T	12	34.3	0.762	1.040	0.13	4.3	5.5
Balanites glabra	T	33	33.7	0.369	2.860	0.13	2.1	5.1
Grewia ferruginea	Sh	32	496.0	0.020	2.773	1.92	0.1	4.8
Kleinia squarrosa	Sh	32	496.0	0.013	2.773	1.92	0.1	4.8
Grewia flavescens	Sh	32	384.0	0.008	2.773	1.49	0.0	4.3
Balanites aegyptiaca	T	28	31.0	0.262	2.426	0.12	1.5	4.0
Grewia erythrea	Sh	23	421.3	0.025	1.993	1.63	0.1	3.8
Buckollia volubilis	Cl	24	416.0	0.012	2.080	1.61	0.1	3.8
Agava sisalana	Sh	24	373.3	0.025	2.080	1.45	0.1	3.7
Cryptostegia grandiflora	Cl	19	448.0	0.012	1.646	1.74	0.1	3.5
Grewia bicolor	Sh	20	410.7	0.015	1.733	1.59	0.1	3.4
Aloe pirottae	Sh	17	432.0	0.025	1.473	1.67	0.1	3.3
Capparis tomentosa	Sh	18	266.7	0.120	1.560	1.03	0.7	3.3
Periploca linearifolia	Cl	19	362.7	0.012	1.646	1.40	0.1	3.1
Berchemia discolor	T	17	15.3	0.268	1.473	0.06	1.5	3.0
Capparis fasicularis	Sh	13	293.3	0.120	1.127	1.14	0.7	2.9
Dichrostachys cinerea	Sh	15	325.3	0.021	1.300	1.26	0.1	2.7
Acokanthera schimperi	Sh	14	309.3	0.043	1.213	1.20	0.2	2.7
Acacia seyal	T	5	30.0	0.341	0.433	0.12	1.9	2.5
Acacia albida	T	19	11.3	0.105	1.646	0.04	0.6	2.3
Boswellia neglecta	T	11	30.7	0.204	0.953	0.12	1.1	2.2
Euphorbia abyssinica	T	15	17.0	0.124	1.300	0.07	0.7	2.1
Sarcostemma viminale	Cl	13	154.7	0.010	1.127	0.60	0.1	1.8
Rhus natalensis	Sh	11	154.7	0.032	0.953	0.60	0.2	1.7

Premna oligotricha	Sh	10	197.3	0.012	0.867	0.76	0.1	1.7
Plicosepalus curviflorus	Sh	13	122.7	0.010	1.127	0.48	0.1	1.7
Crotalaria quartiniana	Cl	7	229.3	0.010	0.607	0.89	0.1	1.6
Euphorbia cryptospinosa	Sh	9	165.3	0.012	0.780	0.64	0.1	1.5
Asparagus leptocladodius	Sh	11	112.0	0.006	0.953	0.43	0.0	1.4
Grewia schweinfurthii	Sh	5	208.0	0.025	0.433	0.81	0.1	1.4
Acacia etbaica	T	10	7.7	0.072	0.867	0.03	0.4	1.3
Commiphora schimperi	T	10	18.0	0.058	0.867	0.07	0.3	1.3
Allophylus rubifolius	Sh	7	149.3	0.010	0.607	0.58	0.1	1.2
Saralluma speciosa	Sh	7	160.0	0.002	0.607	0.62	0.0	1.2
Acacia oerfota	Sh	6	122.7	0.038	0.520	0.48	0.2	1.2
Chionothrix latifolia	Sh	7	138.7	0.011	0.607	0.54	0.1	1.2
Sterculia africana	T	7	4.3	0.101	0.607	0.02	0.6	1.2
Steganotaenia araliacea	T	8	7.7	0.083	0.693	0.03	0.5	1.2
Solanum incanum	Sh	8	90.7	0.009	0.693	0.35	0.0	1.1
Plectranthus puberulentus	Sh	7	112.0	0.004	0.607	0.43	0.0	1.1
Commicarpus sinuatus	Cl	8	74.7	0.013	0.693	0.29	0.1	1.1
Senna singueana	Sh	6	112.0	0.008	0.520	0.43	0.0	1.0
Euclea schimperi	Sh	4	154.7	0.001	0.347	0.60	0.0	1.0
Canthium setiflorum	Sh	5	96.0	0.025	0.433	0.37	0.1	0.9
Carissa spinerum	Sh	5	112.0	0.003	0.433	0.43	0.0	0.9
Oncoba spinosa	T	5	7.0	0.073	0.433	0.03	0.4	0.9
Capparis sepiaria	Sh	5	85.3	0.005	0.433	0.33	0.0	0.8
Jusminum eminii	Cl	4	64.0	0.013	0.347	0.25	0.1	0.7
Salvadora persica	T	5	3.7	0.038	0.433	0.01	0.2	0.7
Commiphora erythraea	T	5	8.7	0.035	0.433	0.03	0.2	0.7
Dodonaea angustifolia	Sh	4	74.7	0.003	0.347	0.29	0.0	0.7
Lepidagathis calycina	Sh	4	64.0	0.003	0.347	0.25	0.0	0.6
Acacia nilotica	T	5	8.7	0.020	0.433	0.03	0.1	0.6
Combretum molle	T	4	3.3	0.020	0.347	0.01	0.1	0.5

Habit; T = tree; Sh = shrub; Cl = climber; S/T = shrub/tree

Appendix 5. List of food plants. Habit: Sh-shrub, T-tree, cl-climber, H-herb; Part used - L = leaf, S = seed, G = gum, F = fruit; Mode of consumption: R = raw, C = cooked.

No.	*Scientific name*	Family	Local name	Habit	Part used	Mode of consum.
1	*Acacia albida*	Fabaceae	Gerbi(Or)	T	S/F	R
2	*Acacia brevispica*	Fabaceae	Hamareysa(or)	Sh	L	like tea
3	*Acacia mellifera*	Fabaceae	Bilaila(oro)	Sh/T	G	R
4	*Acacia nilotica*	Fabaceae	serkema	Sh	G	R
5	*Acacia senegal*	Fabaceae	Sobensa(oro)	Sh	G	R & C
6	*Acacia seyal*	Fabaceae	Wachu(oro), wadhi(som)	T	G	R
7	*Acacia tortilis*	Fabaceae	Dhedhecha	T	F	R
8	*Acokanthera schimperi*	Apocynaceae	Keraru(oro)	Sh/T	F	R
9	*Balanites aegyptiaca*	Balanitaceae	kutka(oro)	T	F	R
10	*Balanites glabra*	Balanitaceae	Bedeno	T	F	R
11	*Berchemia discolor*	Rhaminaceae	Jejeba(oro),dheen(S)	Sh	F	R
12	*Carissa spinerum*	Apocynaceae	Agemsa(oro)	Sh	F	R
13	*Corchorus trilocularis*	Tiliaceae	Dhangego nama	cl	S/F	R
14	*Cordia monoica*	Boraginaceae	Medhero(oro)	T	F	R
15	*Cordia ovalis*	Boraginaceae	Medhero(oro)	Sh	F	R
16	*Euclea schimperi*	Ebenaceae	mieysa	Sh	F	R
17	*Ficus vasta*	Moraceae	kiltu	T	G	R
18	*Flueggea virosa*	Euphorbiaceae	Kechachule(oro)	H	F	R
19	*Grewia bicolor*	Tiliaceae	Suta nekebu(oro)	Sh	F	R
20	*Grewia erythraea*	Tiliaceae	Dheka(Or)	Sh	F	R
21	*Grewia ferruginea*	Tiliaceae	Ogemdi gurati	Sh	F	R
22	*Grewia flavescens*	Tiliaceae	Tateysa(oro)	Sh	F	R
23	*Grewia schweinfurthii*	Tiliaceae	Midha-medew,Midha-gure	Sh	F & L	R
24	*Grewia villosa*	Tiliaceae	Ogemdi adi(oro)	Sh	F	R
25	*Oncoba spinosa*	Flacourtiaceae	Jilbo(oro)	T	F	R
26	*Opuntia ficus-indica*	Cactaceae	Tini (oro & Som)	Sh/T	F	R
27	*Pappea capensis*	Sapindaceae	Biqee	T	F	R
28	*Rhus natalensis*	Anacardiaceae	d0bobeeysaa	Sh	F	R
29	*Salvadora persica*	Salvadoraceae	Ade(oro), Geres(som)	T	F	C
30	*Tamarindus indica*	Fabaceae	Roka (oro)	T	F	R
31	*Ximenia caffra*	Olacaceae	Hudha-jeldo(oro)	Sh	F	R
32	*Ziziphus spina-christi*	Rhaminaceae	Kurkura(oro)	T	F	R

Appendix 6. List of human medicinal plants in the study area

Habit: Sh-shrub, T-tree, cl-climber, H-herb; Part used (PU) L-leaf, B-bark, St-stem, G-gum, Sa-sap, R-root, F-fruit, and Ne-nectar. MP (method of preparation); PA (part administered).

No.	*Scientific name*	Family	Local name	Habit	Disease treated	PU	MP	PA
1	*Abutilon fruticosum*	Malvaceae	Balaanbal(S)	Sh	wound	L	crush& tie	dermal
2	*Acacia albida*	Fabaceae	Gerbi	T	stomachach/diarrhea	B	concoction	oral

3	*Acacia brevispica*	Fabaceae	Hamareysa	Sh	headach	L	hot infusion(boil & drunk)	oral
4	*Acacia nilotica*	Fabaceae	Serkema,Mese-aga(som)	T	mouth infection toothach for bad smell of mouth	L L L & B	crushed crushed decoction	chew & spit chew & spit herbal bath
5	*Acacia oerfota*	Fabaceae	Ajo	Sh	anal parasitic problems bad sprit & 'mich'	St B	rubbed crush& tie	anal dermal
6	*Acacia robusta*	Fabaceae	Wangeyo	T	malaria	R	concoction	oral
7	*Acacia Senegal*	Fabaceae	Sobensa	Sh	eye disease backbone pain constipation stomach ach	G G G G	decoction eaten raw eaten raw eaten raw	oral oral oral oral
8	*Acacia tortilis*	Fabaceae		T	throat infection	L	concoction	oral
9	*Acokanthera schimperi*	Appocynaceae		Sh/T	Mosquito repellent/malaria	St	smoke bath	smoke bath
10	*Aloe pirottae*	Aloaceae	Hargeysa nama, de-ar(som) Gebedherta(S) Hargeysa(or)	Sh	tropical ulcer eye disease malaria snake bite gal-stone malaria anti-insect	L Sa L L L L L	fluid extract ointment concoction concoction fluid extract fluid extract smoke bath	dermal eye oral oral oral oral smoke bath
11	*Asparagus leptocladodius*	Asparagaceae	Keleme	Sh	Kidney & liver disease vomiting (children) " " "	L R R	crushed concoction hot infusion(boil & drunk)	herbal bath oral oral
12	*Balanites aegyptiaca*	Balanitaceae	Kutka	T	snake bite weak sex	R F	crush& tie eaten raw	dermal oral
13	*Balanites glabra*	Balanitaceae	Bedeno	T	fever	R	eaten raw	herbal bath
14	*Barleria eranthemoides*	Acanthaceae	Kumutu gala	H	infertility of women Rh disease	R R	smake bath smake bath	smoke bath smoke bath
15	*Boscia minimifolia*	Capparidaceae	Meygaag	T	wound	L	crush& tie	dermal
16	*Capparis fascicularis*	Capparidaceae	hida sere	Cl	toothach wound	R R	chewed crush& tie	chew & spit dermal
17	*Capparis sepiaria*	Capparidaceae	Riga gange	Sh	swollen body with pus	L	crush& tie	dermal
18	*Cissus rotundifolia*	Vitaceae	Chobi	Cl	gonorrhea	L	concoction	oral
19	*Commelina stephaniniana*	Commelinaceae	Hola gabis	H	skin fungus	St	cream	dermal

20	*Commiphora schimperi*	Burseraceae	Dekero	T	Vaginal problem after birth	B	smoke bath	smoke bath
21	*Corchorus trilocularis*	Tiliaceae	mulukiya	H	abdomenal disorder	St	concoction	oral
22	*Crotalaria laburnifolia*	Fabaceae		Sh	skin fungus	L	crushed	dermal
23	*Cucumis dipsaceus*	Cucurbitaceae	Hare goge	H	snake bite carnivor bite wound gal-stonehepititus	R F R	crushed crushed concoction	dermal dermal oral
24	*Dodonaea angustifolia*	Sapindaceae	Edechaa	Sh	worm parasite	R	rubbed	anal
25	*Euclea schimperi*	Ebenaceae	mi'esaa	Sh	joint pain	L	hot infusion(boil & drunk)	oral
26	*Euphorbia abyssinica*	Euphorbiaceae Euphorbiaceae	Dharkena Dharkena	T T	stomachach, malaria poor sight, paralysis	Ne Ne	syrup syrup	oral oral
27	*Euphorbia burgeri*	Euphorbiaceae	hadami	Sh	swollen body with pus	L	crush& tie	dermal
28	*Grewia bicolor*	tiliaceae		Sh	stomach disease/worms	L	concoction	oral
29	*Grewia ferruginea*	Tiliaceae	Ogemdi	Sh	kidney infection	F	concoction	oral
30	*Heliotropium aegyptiacum*	Boraginaceae	Maadaaris(S)	H	constipation	R	concoction	oral
31	*Hibiscus dongolensis*	Malvaceae		H	infection	L	crush& tie	dermal
32	*Indigofera amorphoides*	Fabaceae	Jeere(S)	H	heart disease	L	hot infusion(boil & drunk)	oral
33	*Justcia schimperiana*	Acanthaceae	Dhumuga	Sh	swelling at ear	St	others	others
34	*Oncoba spinosa*	Flacourtiaceae	Jilbo	T	eye disease	F	ointment	eye
35	*Opuntia ficus-indica*	Cactaceae	Tini	Sh/T	hair fungus	L	crushed	dermal
36	*Ozoroa insignis*	Anacardiaceae	Rukeylu	T	tropical ulcer	R	crush& tie	dermal
37	*Plectranthus cylinderaceus*	Lamiaceae	Barbarisha gara	Sh	spots on skin on infants spots on skin on infants	L L	crushed smoke bath	herbal bath smoke bath
38	*Sarcostemma viminale*	Asclepiadaceae		Cl	Hemoohoid	L & R	crushed	anal
39	*Senna italica*	Fabaceae		H	Stomachach/wormexpel	L	boil & drunk	oral
40	*Senna obtusifolia*	Fabaceae		Sh	snake bite	R	crush& tie	dermal
41	*Tamarindus indica*	Fabaceae	Roka	T	stomachach/parasite	F	concoction	oral
42	*Trachilia emetica*	Meliaceae	Ununu	T	Vomiting	B	concoction	oral
43	*Ziziphus spina-christi*	Rhaminaceae	Kurkura	T	swollen body	L	concoction	herbal bath

Appendix.7 Ten top human diseases in the Erer valley and surroundings for 2004/2005

Type of disease	No. of cases treated/year	percent
Internal parasites	5461	34.6
Malaria	3247	20.5
Pneumonia	1947	12.3
Gastritis	980	6.2
All types of disease of gum	907	5.7
Anemia	897	5.6
Eye diseases	814	5.1
Upper respiratory tract infections	590	3.7
Infection of skin & subcutaneous tissue	528	3.4
Acute & chronic utaites media	431	2.7
Total	**15802**	**100**

(Source- Erer clinic)

Appendix 8. List of ethnovetrenary medieine.

DT=Disease treated; PU=part used; MP= method of preparation; PA= part administered.
Cr-crushed, Ti-tie, Pd-pounded, Oi-oientment, Co-concoction, D-dried, Pl-planting, Sm-small, Wa-warm, Sa-sap and Cm-cream. Ex-external, O-oral, Ey-eye, No-nose, and M-mouth.

No.	*Scientific name*	Family	Local name	Habit	DT	PU	MP	PA
1	*Abutilon fruticosum*	Malvaceae	Balaanbal(S)	Sh	wound	L	Cr & Tie	Ex
2	*Acalypha fruticosa*	Euphorbiaceae	Dhirii(Or)	Sh	Lymphatic swelling	L	Cr &Pd	O
3	*Aloe pirottae*	Aloaceae		Sh	external infection	Sa	Cm	Ex
4	*Balanites aegyptiaca*	Balanitaceae	kutka(Or)	T	infeceted eye	L	Oi	Ey
	Balanites aegyptiaca	Balanitaceae	kutka	T	weak mating	F	Ra	O
5	*Boscia minimifolia*	Capparidaceae	Meygaag(S)	T	wound	L	Cr	Ex
6	*Capparis tomentosa*	Capparidaceae	gemora(Or)	Sh	infected eye	F	Oi	Ey
7	*Cissus rotundifolia*	Vitaceae	Chobi(Or)	Cl	wound	L	Cr	Ex
	Cissus rotundifolia	Vitaceae	Chobi	Cl	insect bite	L	Co	Ex
	Cissus rotundifolia	Vitaceae	Chobi	Cl	anti- snake	L	Dr	No
8	*Commicarpus plumbagineus*	Nyctaginaceae	Kontom adi(Or)	Cl	cattle wound	R	Cr	Ex
9	*Commiphora erythraea*	Burseraceae	Hameysa,kedhon	T	bad sprit	L	Pl	Ex
10	*Cucumis dipsaceus*	Cocurbitaceae	Haree gogee	H	cough	F	Co	O
	Cucumis dipsaceus	Cocurbitaceae	Haree gogee	H	camel wound	F	Cr	Ex
11	*Cyphostemma adenocaule*	Vitaceae	Armoo	H	camel wound	L	Cr	Ex
12	*Dodonaea angustifolia*	Sapindaceae	Edecha	Sh	camel wound	L	Cr	Ex

13	*Hibiscus dongolensis*	Malvaceae		H	infection	L	Cr	Ex
14	*Kleinia squarrosa*	Asteraceae	Luko	Sh	continous tear	R	Cr	M &No
15	*Leucas abyssinica*	Lamiaceae		Sh	infected eye	L	Cr	Ey
16	*Ozoroa insignis*	Anacardiaceae	Rukeylu	T	tropical ulcer	R	Cr	Ex
17	*Plectrathus barbatus*	Lamiaceae	Barbarisha	H	milk spoilage	L	Co	O
18	*Plectranthus puberulentus*	Lamiaceae		Sh	remove placenta	L	Co	O
19	*Solanum incanum*	Solanaceae	Hidi gurati (or)	Sh	shape oxen behaviour	R	Cr &sm	No
	Solanum incanum	Solanaceae	Hidi gurati (or)	Sh	romove spine in skin	F	wa & Ti	Ex
20	*Withania somnifera*	Solanaceae	Hidi gudeye	H	lymphatic swelling	L&R	Co	O

Appendix 9. List of forage plants in the study area. Habit: Sh-shrub, T-tree, cl-climber, H-herb;PU (part used): Br-branch, F-fruit, L-leaf, Fl-flower, Ag-above ground.

Scientific name	family	Local name	Habit	PU	Remark
Abutilon fruticosum	Malvaceae	Balaan-baal(S)	Sh	Br	camel & goat
Acacia albida	Fabaceae	Gerbi(oro)	T	Br&F	mainly by goat
Acacia brevispica	Fabaceae	Hamareysa(oro)	Sh	L&Br	eaten by all
Acacia etbaica	Fabaceae	Dedoti(oro)	T	L	eaten by all
Acacia mellifera	Fabaceae	Bilaila	Sh	L	all animals / bee forage
Acacia nilotica	Fabaceae	Serkema(oro)	T	F&L	Goats & camels
Acacia oerfota	Fabaceae	Ajo	Sh	L	camel & Goat
Acacia robusta	Fabaceae	Wangeyo(oro)	T	L	camel & Goat
Acacia senegal	Fabaceae	Sobensa(oro)	Sh	L&Br	dry & wet season feed
Acacia tortilis	Fabaceae	Dhedhecha	T	Br&F	all
Asparagus leptocladodius	Asparagaceae	Keleme sere	Sh	Br	goat
Balanites aegyptiaca	Balanitaceae	Kutka	T	L&Br	all animals use
Balanites glabra	Balanitaceae	Bedeno	T	L&Br	all
Berchemia discolor	Rhamnaceae	Jejeba(oro), dheen(S)	T	L,F,Fl	all animals / bee forage
Blepharis edulis	Acanthaceae	Kumutu gaalaa	H	Ag	camel
Cenchrus ciliaris	Poaceae	Gaaroolee(S0	G	L	all
Chloris pycnothrix	Poaceae		G	Ag	cattle
Chloris Virgata	Poaceae		G	Ag	cattle
Commelina stephaniniana	Commelinaceae	Holagebis	H	Ag	all
Commicarpus sinuatus	Nyctaginaceae	kontom dima	H	Ag	all
Commiphora erythraea	Burseraceae	Hameysa, kedhon	T	L&Br	feed for all/Ever green
Convolvulus siculus	Covolvulaceae		H	Ag	all
Cordia africana	Boraginaceae	Welensu (oro)	T	L	all animals use
Cynodon dactylon	Poaceae		G	Ag	cattle
Dichrostachys cinerea	Fabaceae	Jirme (oro)	Sh	L&F	best feed for all animals

Eragrostis aspera	Poaceae		G	Ag	cattle
Eragrostis lepida	Poaceae		G	Ag	cattle
Eragrostis papposa	Poaceae		G	Ag	cattle
Euphorbia cryptospinosa	Euphorbiaceae	Dhangego werabeysa	Cl	St	camel & goat feed
Grewia bicolor	Tiliaceae	Suta nekebu	Sh	L	all animals use
Grewia erythrea	Tiliaceae	Dheka	Sh	L&F	all
Grewia ferruginea	Tiliaceae	Ogemdi	Sh	L	best feed for all animals
Grewia tenax	Tiliaceae	alibal	Sh	L&Br	all animals use
Helitropium aegyptiacum	Boraginaceae	Maadaariis(S),Medheroo	H	L	all
Indigofera hochstetteri	Fabaceae	Sogida re'ee	H	Ag	all
Ipomea obscura	Convolvulaceae	Aneysu	Cl	L	cattle
Jusminum grandiflorum	Oleaceae	Biluu	Cl	Br	all
Kleinia squarrosa	Asteraceae	Luko	Cl	Br&L	camel & goat feed
Lanthana camara	Verbenaceae	Beke arkete(oro)	Sh	L	use in dry season
Lepidagathus calycina	Acanthaceae	Echini,dhala,Hajinka(S)	Sh	L&Br	all (specialy dry season)
Leucas martinicensis	Lamiaceae	Dunfuro	H	Ag	all/ bee forage
Melinis repens	Poaceae		G	Ag	cattle
Opuntia ficus-indica	Cactaceae	tini	Sh/T	L&F	camel
Opuntia stricta	Cactaceae	Kenchere	Sh	L&F	camel
Panicum maximum	Poaceae	citaa arbii	G	Ag	all
Panicum monticolum	Poaceae	citaa	G	Ag	all
Papea capensis	Sapindaceae	Bika, Biqa (oro)	T	L	dry season feed
Plectrathus cylindraceus	Lamiaceae	Berbarisha gara	Sh	L&Br	all use it (good feed)
premna oligotricha	Verbenaceae	Jac-jakle(S)	Sh	Br	Goat & camel
Prosopis juliflora	Fabaceae	Ged-adab	Sh	Br	camel/goat
Ruellia patula	Acanthaceae	Dhekdhek	H	Ag	all
Senna italica	Fabaceae		H	Ag	all
Senna obtusifolia	Fabaceae		Sh	L	all
Senna singueana	Fabaceae		Sh	L	all
Tylosema fassoglensis	Fabaceae		Cl	L	cattle
Vernonia cinarescens	Asteraceae	Hill(S)	Sh	L	camel & goat
Ximenia caffra	Olacaceae	Hudha jeldo (oro)	Sh	Fr	all animals use
Ziziphus spina-christi	Rhamnaceae	Kurkura(oro)	T	L	goats & camel use more

Appendix 10. List of plant species used for firewood and charcoal making. Habit: T=tree, sh = shrub.

Scientific name	family	Local name	Habit	Uses
Acacia albida	Fabaceae	Gerbi	T	both
Acacia bussei	Fabaceae	Hallo	T	Both
Acacia etbaica	Fabaceae	Dedoti,Sog-sog(S)	T	both
Acacia mellifera	Fabaceae	Bilaila	Sh	firewood
Acacia nilotica	Fabaceae	Serkema	T	both
acacia oerfota	Fabaceae	Ajo	T	Both

Acacia robusta	Fabaceae	wangeyo	T	both
Acacia senegal	Fabaceae	Sobensa	Sh	firewood
Acacia seyal	Fabaceae	Wachu	T	both
Acacia tortilis	Fabaceae	hedhecha	T	both
Acalypha fruticosa	Euphorbiaceae	Dhirii	Sh	firewood
Balanites aegyptiaca	Balanitaceae	Kutka	T	firewood
Balanites glabra	Balanitaceae	Bedeno	T	firewood
Berchemia discolor	Rhaminaceae	Jejeba	T	both
Boswellia neglecta	Burceraceae	Muka libaneta	T	firewood
Cantium setiflorum	Rubiaceae		Sh	firewood
Carissa spinerum	Apocynaceae	Agemsa	Sh	fire wood
Commiphora erythraea	Burceraceae	Hameysa, kedhon	T	fire wood
Commiphora schimperi	Burceraceae		T	firewood
Dichrostachys cinerea	Fabaceae	Jirme	T	firewood
Euphorbia polyacanthra	Euphorbiaceae	Hdami	Sh	firewood
Lantana camara	Verbenaceae	Beke arkete	Sh	firewood
Ozoroa insignis	Anacardiaceae	Rukeysa, Ogol(S)	T	charcoal
Pappea capensis	Sapindaceae	Bika/Biqa	T	firewood
Rhus natalensis	Anacardiaceae	Riga werabo	T	firewood
Sterculia africana	Sterculiaceae	Geri	T	firewood
Terminalia briwnii	Combretaceae	Bireeyssa	T	firewood
Trachilia emetica	Meliaceae	Ununuu	T	firewood

Appendix 11. List of plant species used for construction and crafts. Habit: T=tree, sh = shrub, H = herb. PU (Part Used): St = stem, Ba = bark.

Scientific name	Family	Local name	Habit	PU	Uses
Acacia albida	Fabaceae	Gerbi	T	St	house hold utensils
Acacia albida	Fabaceae	Gerbi	t	St	make bee hive
Acacia brevispica	Fabaceae	Hamareysa	Sh	St	house construction
Acacia bussei	Fabaceae	Hallo	T	St	house construction
Acacia bussei	Fabaceae	Hallo	t	St	farm tools
Acacia mellifera	Fabaceae	Bilaila	t	St	farm tools
Acacia nilotica	Fabaceae	serkema	T	St	house construction
Acacia oerfota	Fabaceae	Ajo	Sh	Ba	house construction
Acacia robusta	Fabaceae	Wangeyo	T	St	house construction
Acacia robusta	Fabaceae	Wangeyo	t	St	farm tools
Acacia seyal	Fabaceae	Wachu	T	St	house construction
Acacia tortilis	Fabaceae	Dhedhecha	T	St	house construction
Acacia tortilis	Fabaceae	Dhedhecha	T	St	mortar &pistil
Acalypha fruticosa	Euphorbiaceae	Dhiri	Sh	St	temporary house
Agava sisalana	Agavaceae	Alge	Sh/tr	Fiber	rope making

Balanites aegyptiaca	Balanitaceae	Kutka	t	St	farm tools
Balanites glabra	Balanitaceae	Bedeno	t	St	farm tools
Berchemia discolor	Rhaminaceae	Jejeba, Dheen	T	St	house construction
Berchemia discolor	Rhaminaceae	Jejeba	T	St	large mortar
Berchemia discolor	Rhaminaceae	Jejeba,Dhen (Som)	t	St	farm tools
Cissus rotundifolia	Vitaceae	Chobi	Cl	St & L	house hold furniture
Comberatum molle	Combretaceae	Ogel biyo (oro)	T	St	house construction
Commiphora erythraea	Burceraceae	Hameysa, kedhon	T	St	Cultural utensils
Commiphora erythraea	Burceraceae	Hameysa, kedhon	t	St	camel bell
Cordia africana	Boraginaceae	wedeysa	T	St	house construction
Cordia africana	Boraginaceae	Wedeysa	T	St	house hold furniture
Cordia monoica	Boraginaceae	Medhero	Sh	St	house construction
Cordia monoica	Boraginaceae	Medhero	Sh	St	farm tools
Dichrostachys cinerea	Fabaceae	Jirme	Sh	St	house construction
Dichrostachys cinerea	Fabaceae	Jirme	T	St	mortar &pistil
Dichrostachys cinerea	Fabaceae	Jirme	sh	St	farm tools
Euclea schimperi	Ebenaceae	mi'eysa	Sh	St	house hold utensils
Euphorbia abyssinica	Euphorbiaceae	Dharkena	T	St	to make door
Ficus vallis-choudae	Moraceae	Oda	T	St	house construction
Ficus vallis-choudae	Moraceae	Oda	T	St	house hold utensils
Grewia ferruginea	Tiliaceae	ogemdi	Sh	St	house construction
Grewia schweinfurthii	Tiliaceae	Midha-medew,midha-gure	Sh	St	basket
Grewia tenax	Tiliaceae	Alibal, Dhul-felidh (s)	Sh	St	house construction
Premna oligotricha	Verbenaceae	Jac jacle	Sh	St	frame/container
Premna oligotricha	Verbenaceae	jak-jakle	Sh	St	frame for milk, butter container
Rhus natalensis	Anacardiaceae	Riga werabo	Sh	St	house hold utensils
Rhus natalensis	Anacardiaceae	Riga werabo	Sh	St	farm tools
Sterculia africana	Sterculiaceae	Geri	T	St	spoon
Sterculia africana	Sterculiaceae	Geri	t	St	farm tools
Tamarindus indica	Fabaceae	Roka	T	St	house construction
Terminalia briwnie	Combretaceae	bireeysaa	t	St	farm tools
Terminalia brownie	Combretaceae	Bireysaa	T	St	house construction
Trachilia emetica	Meliaceae	Unununu	t	St	farm tools
Ziziphus spina-christi	Rhaminaceae	Kurkura	T	St	house construction
Ziziphus spina-christi	Rhaminaceae	Kurkura	T	St	bed, farm tools

Appendix 12. List of plants used for other purposes. Habit: T=tree, sh = shrub, Cl=climber H = herb

Scientific name	Family	Local name	Habit	Part used	Uses
Acacia brevispica	Fabaceae	Hamareysa	Sh	branches	cultural/wedding
Acacia brevispica	Fabaceae	Hamareysa	Sh	leaf	stimulant
Acacia brevispica	Fabaceae	Hamareyssa	Sh	stem smoke	flavor milk
Acacia bussei	Fabaceae	Hallo	t	flower	indicator of season
Acacia nilotica	Fabaceae	Serkema, mere-aga(s)	t	bark	to make ink
Acacia nilotica	Fabaceae	Serkema, mere-	t	bark	to soften leather

		aga(s)			
Acacia robusta	Fabaceae	Wangeyo	t	flower	indicator of season
Acacia seyal	Fabaceae	Wachu	t	crush leaf/gum	to fix ink
Acacia tortilis	Fabaceae	Dhadhacha	t	live shade	cultural meeting
Acalypha fruticosa	Euphorbiaceae	Dhirii	Sh	leaf	flavor butter
Acalypha fruticosa	Euphorbiaceae	Dhirii	Sh	leaf	butter preservative
Acokanthera schimperi	Apocynaceae	Keraru	Sh	leaf	anti-crop pest
Agava sisalana	Agavaceae	Alge	Sh/tr	stem	tooth brush
Aloe pirottae	Aloaceae	Hargeysa	Sh	leaf	colour
Aloe pirottae.	Aloaceae	Hargeysa	Sh	stem smoke	attract honey bees
Asparagus leptocladodius	Asparagaceae	Kelema sere	Sh	stem	cultural pencil
Balanites glabra	Balanitaceae	Bedeno	t	dry stem	to collect honey from hive
Balanites glabra	Balanitaceae	Bedeno, Kedi (Som)	t	stem smoke	flavor milk
Berchemia discolor	Rhaminaceae	Jejeba,Dhen (Som)	t	live plant	cultural meeting
Boscia minimifolia	Capparidaceae	Mregal, meygag(Som)	t	stem smoke	flavor milk
Canthium setiflorum	Rubuaceae		t	leaf & stem	flavor milk
Capparis fascicularis	Capparidaceae	Hida sere	Cl	stem	to make beehive
capparis tomentosa	Capparidaceae	Gemora	Sh	fruit & leaf	Toxic
Carissa spinerum	Apocynaceae	Agemsa	Sh	stem	increase bees population
Commiphora erythraea	Burceraceae	Hameysa, kedhon	t	gum	to make candle
Commiphora erythraea	Burceraceae	Hameysa, kedhon	t	Gum &resin	fragrance
Commiphora erythraea	Burceraceae	Hameysa, kedhon	t	stem	tooth brush
Commiphora schimperi	Burceraceae	Dekero	t	bark & resine	frankinces
Eucilea schimperi	Ebenaceae	mi'eysaa	Sh	stem	herding stick
Euphorbia polyacanthra	Euphorbiaceae	Hadami	Sh	flower	indicator of season
Ficus vallis-choudae	Moraceae	Oda	t	live shade	cultural meeting
Ficus vasta	Moraceae	Kiltu	t	resin	fixative
Grewia ferruginea	Tiliaceae	Ogemdi	Sh	leaf	flavor tea
Kleinia squarrosa	Asteraceae	Luko	Sh	leaf	spice
Ocimum lamiifolium	Lamiaceae		H	leaf	perfume
Ozoroa insignis	Anacardiaceae	Rukeysa, Ogol(som)	t	stem	natural beehive
Plectranthus cylindraceus	Lamiaceae	Berbarisha	H	stem	source of fire
Premna oligotricha	Verbenaceae	jak-jakle	Sh	stem	to make herding stick
Rhus natalensis	Anacardiaceae	Riga werabo	Sh	stem	tooth brush
Rhus natalensis	Anacardiaceae	Riga werabo	Sh	stem smoke	to clean bee hive
Rhus natalensis	Anacardiaceae	Riga werabo	Sh	stem smoke	flavor milk
Salvadora persica	Salvadoraceae	Ade	t	stem	tooth brush
Tagetes minuta	Asteraceae	Harams ajawaa	H	stem & leaf	ant-crop pest
Tagetes minuta	Asteraceae	Harams ajawaa	H	stem & leaf	kill insects of night bite
Tagetes minuta	Asteraceae	Harams ajawaa	H	stem & leaf	used under havested crop
Tamarindus indica	Fabaceae	Roka	t	gum	ink

Ziziphus spina-christi	Rhaminaceae	Kurkura	t	leaf	colouring hair
Ziziphus spina-christi	Rhaminaceae	Kurkura	t	leaf & stem	to soften dead person body
Ziziphus spina-christi	Rhaminaceae	Kurkura	t		remove bad smell of dead body

Appendix 13. List of Key informants in the study area

Name	Sex	Age	Locality
Abdi Ali	M	55	Gende Abdi
Ali Dol	M	32	"
Hassen Ahmed	M	35	"
Ahmed Abdi	M	50	"
Hasse Mumed Liman	M	40	MfM camp
Mohammod Ahmed (Kegnur)	M	42	"
Le'ag Mohammod	M	28	Wolbi
Mohammod Yusuf	M	80	"
Bale Haji Ebrahim	M	60	Raree Adem
Deko Umer	M	38	Gende Negeya
Mohammod Ahmed Umer	M	56	"
Abdi Ali Beker	M	40	Kurfaa Guratii
Bekero Ahmed	M	54	"
Abadir Haji Ali	M	75	Raree Adem
Abdurehiman Bale Ahmed	M	38	"