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ELEPHANT AND ANTHROPOGENIC IMPACTS ON WOODY PLANT SPECIES IN BABILE ELEPHANT SANCTUARY, EASTERN ETHIOPIA


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ABBREVIATIONS AND ACRONYMS

a.s.l	Above sea level
BES	Babile Elephant Sanctuary, or Sanctuary
CSA	Central Statistical Agency
DBH	Diameter at Breast Height
EHZPEDO	East Hararge Administrative Zone Planning and Economic Development Office
EWCO	Ethiopian Wildlife and Conservation Organization
EWNHS	Ethiopian Wildlife and Natural History Society
FAO	Food and Agricultural Organization of United Nations
ICRAF	International Centre for Research in Agro-forestry
IUCN	International Union for the Conservation of Nature and Natural Resources (or World Conservation Union)
NMSA	National Metrological Service Agency
PRA	Participatory Rural Appraisal
SIDA	Swedish International Development Agency
SPSS	Statistical Package for Social Science
UNEP	United Nations Environmental Programme
WCMC	World Conservation Monitoring Center
WRI	World Resource Institute

ABSTRACT

Results from this study present an assessment for the possible elephant (*Loxodonta africana*) and anthropogenic impacts on woody plant species to evaluate natural resource management scheme. Research was carried out for seven months, from September to December 2006, and from March to May 2007 in Babile Elephant Sanctuary, eastern Ethiopia. Stratified sampling method was used and a total of 52 woody plant species were recorded. Of these, elephant impacts were observed on 28 (53%) species belonging to 12 families. Furthermore, 13 (45.8%) of these species were trees and 15 (54.2%) shrubs. The total density of these woody under the impacts of elephant was found to be 11,169.3 individuals/ha while the mean density is 399 ± 156. Elephant-induced damage to trees and shrubs that dominated the vegetation biomass suggested that elephants had a random impact on the vegetation throughout the riverine and woodland vegetations. There was size variation in the proportion of woody plants damaged by elephants. In riverine vegetation, saplings, small trees and medium-sized trees showed higher-than-average impact levels. In woodland vegetation, large, medium and small trees showed impact levels above the overall mean across all stems. The most common damage from the elephants was branch and stem breaking, felling and uprooting of the whole trees or shrubs. The least frequent damage class recorded in this study was bark stripping. The riverine vegetation show relatively more felled woody species (22.61%) than the woodland (18.19%) although woodland areas have a higher proportion uprooted (10.44%) species than riverine (5.26%). Tree and shrub species were utilized by the local community (anthropogenic) for four main purposes: medicinal, fencing, firewood, and shelter. These uses were mainly confined to four key species: *Acacia mellifera, Acacia senegal, Acacia tortilis* and *Balanites glabra*. Human-elephant conflict was manifested in the decline in tree and shrub cover due to charcoal burning, land use changes particularly agricultural expansion and fencing. Even though tree and plant resources were still available, it is important to monitor their use to avert potential over exploitation.

Key words: African elephant, anthropogenic impact, human-elephant conflict, woody species.

1. INTRODUCTION

The vegetation structure of African savannas is in a continuous state of transition, leading to shifting mosaics of woodland and open grasslands. Savanna systems are characterized by a structure that can best be described as wooded grassland where the woody vegetation comprises mature trees and shrubs and where the herbaceous layer is dominated by perennial grasses (Mbuya *et al*., 1994).

Disturbance by humans, mega-herbivores and other agents are common to a variety of natural systems and populations, and play a vital role in determining species richness and the structure of plant and animal communities. However, the limits of disturbance that a population can withstand are usually unknown. To satisfy their nutrient requirements, herbivores selectively forage different parts of the landscape at different scales and, together with climate and fire, affect the balance between woody and herbaceous vegetation (Augustine and McNaughton, 2004). Large mammalian herbivores in particular can have marked effects on the vegetation composition. These effects range from the determination of both the species composition and the prevailing plant growth form of grasslands, to regulation of the balance between shrub and herbaceous layers (Augustine and McNaughton, 2004).

The African elephant (*Loxodonta africana* Blumenbach, 1797) belongs to the order Proboscidea and family Elephantidae. Elephants are both graceful and beautiful land mammals of aesthetic attraction to local and international tourists. They have major ecological effects on savanna dynamics, playing significant roles in nutrient cycling, seed dispersal, the provision of space, and as a result they are considered as keystone or flagship species (Owen-Smith, 1988; Shoshani *et al.*, 2004). Despite their overall endangered status, extensive protected areas and effective control of poaching have led to the success of elephant conservation in Africa (Douglas-Hamilton, 1987). Continued increase of elephant populations may lead to a decrease in other species.

It is argued that the present spatial restriction of elephant populations by fenced nature reserves or external human pressures intensify their impact on woody plants (Pamo and Tchamba, 2001). Analysis of studies on the feeding ecology of elephants suggests that their effect on the vegetation is variable, from causing detrimental changes in woody species composition to promoting growth of other species, thereby increasing woody species diversity. Since much of the conservation is based on maintaining ecological processes (Jacobs and Biggs, 2002), the nature of the interaction between elephants and vegetations must be fully understood.

One of the diverse wildlife species conserved in Ethiopia's protected areas is the African elephant, *Loxodonta africana* (Blumenbach, 1797). Until the turn of the 19th century, the African elephant was widely distributed in the country (Largen and Yalden, 1987; Yirmed Demeke and Afework Bekele, 2000). Since then, however, the poaching of elephants for ivory and problems associated with human population growth and expansion has reduced the species range and number drastically. As a result, it is restricted to remote protected areas (Largen and Yalden, 1987; EWCO, 1991; Yirmed Demeke, 1997). A recent assessment suggests that the country has lost about 90 percent of its elephant population since the 1980's alone. At present, the country's total number of elephants may not exceed 1000 and these inhabit nine separate localities, one being in Babile region of eastern Hararge.

Following Yirmed Demeke *et al.* (2006), the Babile Elephant Sanctuary (BES) is home to the only surviving elephant population in the farthest Horn of Africa and is estimated to have a minimum of 300 elephants. BES is one of the protected areas, which is being highly declining in size and quality. As a result of mass influx of large farmers and their livestock, the home range of elephants of Babile has shrunk by 65 %. BES was established to protect the population of the isolated elephants, *L. africana*.

The impact of anthropogenic activities on wildlife habitat and species will vary depending on the spatial and temporal scales considered and the persistence of the activities in the landscape. Human induced disturbance has been referred to as one of the major causes of vegetation degradation in developing countries. Protected areas have hardly been managed in Ethiopia due to population pressures (Shibru Tedla, 1995; Feyera Senbeta and Demel Teketay, 2003). Often, the decision made on protected areas do not take due consideration of the interest of stakeholders, especially communities who are dependent on the local resources. As a result, uncontrolled expansion of agriculture and grazing coupled with illegal harvesting of vegetation and other products have been threatening the function of the protected area system in many parts of the country (Zelealem Tefera, 1995). Lack of integration of the livelihood of the local people living around BES and the absence of law enforcement system are the major constraints to the overall conservation efforts.

The knowledge of the factors involved in the deterioration of the ecosystems found inside protection areas are fundamental for appropriate management. Disturbances can lead to vegetation degradation and subsequent reduction of desirable characteristics of an area for nature conservation (Allen-Rowlandson, 1990; Azene Bekele, 1993). Recent socio-economic and land use changes in BES such as the demand for more area for agriculture have reduced the woodland area, increasing the severity of impact both humans and elephants have on woody vegetation. The focus of the current study was evaluation of the impacts humans and elephants have on woody vegetation species in the BES. Local communities are highly dependent on vegetations for fencing, medicine, construction and fuel wood. At the same time, large mammals such as the African elephant selectively utilize the woody vegetations, capable of affecting the vegetation of the region they inhabit. As a consequence of their use of such an inaccessible area, very little was known about their foraging behavior and consequent impact on the vegetation. Concern was expressed over possible impact of humans and elephants on the vegetation patches of the reserve. A need existed for more information on the impact of these on the vegetation in order to guide management decision making. This study was initiated to address these concerns and to come up with the natural resource management scheme.

2. LITERATURE REVIEW

2.1. Elephants in savanna habitats

Elephants are classified as megaherbivores. They weigh more than 1,000 kg (Owen-Smith, 1988) and with their daily food consumption amounts to approximately 150 kg for an adult cow and about 300 kg for an adult bull (Estes, 1992; Cowling and Kerley, 2002). They graze and browse, feeding on a wide range of species (Estes, 1992; Owen-Smith, 1988) but are often extremely selective in their food choice depending on availability, palatability and nutritional quality of forage materials. Dietary preferences of elephants change seasonally and this is seen particularly in the occurrence of grass in the diet which is generally high during the wet season and lowers during the dry season when browse becomes increasingly important (Osborn, 2004).

Elephants occur in a wide variety of habitats and are both diurnal and nocturnal, thus they are considered as cathemeral (Shoshani *et al.*, 2004). Seasonal changes in distribution, home range size and habitat selection of elephants have been well documented in Africa and coincide with seasonal changes affecting food and water availability (Whitehouse and Schoeman, 2003). Due to fluctuations in these resources, elephants show preferences for some habitats and avoid others. During the wet season, elephant distribution is widespread and usually in areas with a high abundance of grass. During the dry season, shrinkage of their range occurs and activity is concentrated near water sources, where tree species are often evergreen (Owen-Smith, 1988).

Differential use of habitat types and seasonal changes in the distribution of elephants has been well documented elsewhere in Africa. Habitat selection appears to coincide with seasonal changes and corresponding food availability. Elephants are distributed in a patchy and discontinuous fashion in areas dominated by woodland (De Boer *et al.,* 2000).

They occur predominantly in riverine and woodland savanna habitats, where they browse on trees and shrubs and are primarily diurnal in habit spending the majority of the day feeding. Elephants favor open or broken savanna habitats where visibility is good and they are less prone to predation (Owen-Smith, 1988). Seasonal use of habitat is probably an important mechanism for survival by reducing impact on the dry season habitats and allowing regeneration of food plant. Because habitat destruction due to overgrazing can reduce the fertility and growth rates of animals, information on elephant habitat use is of crucial importance in population control and habitat management (Barnes, 1982).

2.2. Elephant-vegetation interactions in African savannas

The African elephant dietary intake is considerable and the resulting effects on vegetation can be dramatic (Owen-Smith, 1988). Pronounced reductions in trees and other woody plants due to elephants have been experienced across the continent, including Kenya, Cameroon, Tanzania, and South Africa (Lamprey *et al*, 1967; Douglas-Hamilton and Douglas-Hamilton, 1975; Jacobs and Biggs, 2002). Conservationists and reserve managers have expressed concern about loss of rare or vulnerable trees and a possible concomitant loss of biodiversity. This has led to the paradoxical situation whereby managers of reserves with high elephant densities develop plans to limit or reduce population numbers of an endangered species. As elephants experience human-caused habitat reduction, elimination of migration routes and disturbance (including poaching) may cause previously wide-ranging populations to be confined within reserves inducing sudden changes in vegetation (Pamo and Tchamba, 2001).

2.2.1. Feeding patterns and dietary preference

The feeding behavior of elephants acting together with other ecological and environmental factors governs the level of impact of high elephant densities. Elephants are mixed feeders, ingesting both grass and browse in varying proportions.

Woody plants contain higher levels of crude protein than grasses during the dry season and browsing allows elephants to maintain body condition year-round (Williamson, 1975). Elephants thus tend to increase the percentage of browse in their diet, causing most damage to woody plants, during the dry season. Browsing may also be increased as elephants take refugia in woodlands as a response to human disturbance (De Boer *et al.*, 2000). The overall proportion of browse in the diet has been recorded at levels up to 98.8%, in Hwange National Park, Zimbabwe (Williamson, 1975). Intake of wood and bark tends to increase as the dry season progresses.

Preferred feeding height tends to be below 2 m, the height of the browsed plants being somewhat greater (Smallie and O'Connor, 2000). Plants shorter than 1 m tend to be ignored and other height classes utilized in proportion to their availability (Kalemera, 1989). Other workers have found a preference for adult trees which may lead to switching from stem and leaf browsing to bark stripping as height increases beyond 4 m (Smallie and O'Connor, 2000). Depending on the root system of the tree species, it may be uprooted frequently or simply browsed. Uprooting of adult trees by elephants may serve a social purpose but is chiefly associated with gaining access to fruit and leaves on the upper branches (Mwalyosi, 1987).

Elephant damage to trees includes felling, bark damage and stem breakage resulting from scratching-post behavior to shed ticks. Patterns of damage may be distributed differently by sex, Barnes (1982) notes that elephant cows moved more between plants than bulls, and breeding herds tend to be more selective than bulls in feeding patch and plant choice, apparently to minimize fiber intake.

2.2.2. Patterns of woody plant species change

Elephants can cause a rapid decline of woody plant populations or marked changes in community composition. For example, Caughley (1976) reports on baobab, *Adansonia digitata*, mortality of 15.5% over 6 months at an elephant density of 2 km^2 in the Zambezi Valley, and Osborn (2004) reports a yearly decline in large trees of 14.6% in the Queen Elizabeth National Park, Uganda, as the elephant density approached 1.7 km^2. Marked decline can occur even at lower elephant densities. A sudden increase of elephant density to 0.135 per km^2 in Serengeti National Park, Tanzania, led to a decline of large trees at an annual rate of 6% (Lamprey *et al.*, 1967). The nature and extent of species change also depend on habitat type (Anderson and Walker, 1974). Elephant utilization can alter the vertical structure of the woody plant community, commonly manifested as reduced tree density and increased shrub density.

Browsing may trap plants in more accessible size-classes, although Nellemann *et al*., (2002) argues that such shrublands are unstable, prone to crushes when nutrients are eventually depleted under persistent elephant utilization. Others have noted little structural change even with pronounced impacts (Weyerhaeuser, 1995). Intensity of elephant habitat use and the emergent spatial patterns of change in vegetation, reflect the distribution of elephants across the heterogeneous savanna landscape (Steyn and Stalmans, 2001). Spatial distribution of tree use can be contagious, with preferred trees forming focal points for elephant damage (Croze, 1974).

2.3. Elephant interactions with other ecological and environmental factors

Fire, other browsers, drought and soil/nutrient conditions and other factors can aggravate the extent and pattern of elephant damage to species. Vegetation shifts from woodland to grassland have most often been attributed to the joint action of elephants and fire. While elephants can

impact large or small trees, fire normally acts to suppress re-establishment of the damaged plants to reproductive heights (Trollope *et al.,* 1998; Jacobs and Biggs, 2002).

Fire manipulation has been advocated and employed successfully to manage elephant effects on savanna, using either fire suppression to mitigate damage (Trollope *et al.,* 1998), or controlled burns to alter elephant browsing patterns.

Other browsers act in similar fashion to fire by preventing elephant impacted plants from regenerating to adult heights (Lewis, 1991). The principal agents are giraffe, *Giraffa camelopardalis*, and impala, *Aepyceros melampus*. Other impacts reported include hedging by eland, *Tragelaphus oryx* (Styles and Skinner, 2000) and debarking by buffalo, *Syncerus caffer* and kudu, *T. strepsiceros*. The browsing guild itself can be negatively affected by reduction of woodland by elephants. Extended dry seasons or prolonged droughts can compromise tree viability and amplify negative elephant effects, perhaps even more so than fire (Tafangenyasha, 1997). Elephants may also intensify use of browse during the dry periods or alter habitat use patterns. Elephant impacts may also be associated with nutrient-rich soils (Nellemann *et al.,* 2002), and woodland response to utilization varies with soil conditions. Elephant damage to bark increases tree vulnerability to infestation by wood boring insects and fungi (Jacobs and Biggs, 2002).

2.4. Anthropogenic impact on woody plant species

Anthropogenic changes in vegetation over the past century need to be accounted for when assessing elephant impact. The harvesting and consumption of plant products from natural vegetation is known to account for a large proportion of the livelihood of people living close to such habitats. At the global level, socio-economic and political forces that determine the mode of development in many developing countries play an important role in the processes of vegetation degradation and destruction (Sindiga, 1995).

At the national and local levels, vegetation degradation has been suggested to be linked to rural population pressure, through subsistence farming, grazing, and selective wood extraction as a result of large-scale development projects (World Resources Institute, 1996). Vegetation degradation is defined as the deterioration of the healthy conditions of the vegetation, expressed through changes in its composition, structure and function. Vegetation degradation, unlike deforestation, is not a very obvious phenomenon. The changes are revealed gradually, sometimes not in terms of decrease of area, but represented by qualitative losses, for example, through the reduction of species diversity, increase of invasive species, decrease of the shrub layer, reduction of woody species and biomass decline (IUCN, 1990).

Loss of vegetation cover and biodiversity owing to human-induced activities is a growing concern in many parts of the world. The endeavors to restrain such losses have increasingly focused on the establishment of natural reserves around the world. Many countries, however, do not yet have such protected area systems, which are sufficient to address the socio-economic causes of the treats to biodiversity. Moreover, the achievement of protected area management system may be difficult to assess in many developing countries, since there is at present no established system for monitoring trends in biodiversity changes (Zelealem Tefera, 1995).

2.5. Establishment and management responsibility at Babile Elephant Sanctuary

Before the creation of Babile Wildlife Conservation Area as a Sanctuary, the surrounding vast area was originally known for game hunting site and it was named as Harer-Wabi Shebelle Hunting Area. The area extended as far south as Wabi Shebealle River. However, since then concerns grew as the area has long only been known for comprising a handful of elephant population in the semi-arid region to the eastern part of the country (Stephenson, 1976). Efforts in the protection of the faunal and floral diversity in the newly created elephant sanctuary were successful by legally stopping of hunting of big game in the area. An office was also established

in the town of Harar with few staff of wildlife guards and a warden (Yirmed Demeke *et al*., 2006).

Since then, no additional protection was provided: the area remains ungazetted in the law; it has not yet been upgraded to the status of a national park; no adequate budget has been allotted; and the anti poaching team for law enforcement is performing weakly. Civil unrest in the region since the last 50 years has also aggravated the problem, offering inadequate protection to the species.

The BES is currently experiencing a great deal of strain on natural resources, including trees and shrubs. This can be attributed to a variety of factors such as inappropriate land use practices, particularly expansion of agriculture, increase in human population, overstocking with livestock, environmental degradation and frequent drought conditions which could significantly alter natural regeneration of the vegetation. This study provides insights into the utilization of tree and shrub resources by the local community which are critical in developing action plans that will restore sustainable utilization of plant resources on the sanctuary.

3. OBJECTIVES

3.1. General objective

This project aims to assess and characterize the impact of elephants and humans on woody plant species in Babile Elephant Sanctuary; to evaluate natural resource management scheme.

3.2. Specific objectives

- to identify and document woody plant species influenced by the impacts of elephants,
- to determine the type of woody species and size classes most affected by elephants,
- to compare impacts by elephants at riverine vegetation and woodland habitats,
- to evaluate the implications these biotic impacts on the biodiversity of woody plant species of the study area,
- to asses the abundance, density, population and regeneration structure of woody species impacted by elephants, and
- to study the anthropogenic impacts on woody plant species: establish the use of tree and shrub species by the community; assess their relative frequency and quantities of utilization; and assess declining woody plant species.

4. THE STUDY AREA

4.1. Location and topography

Babile Elephant Sanctuary is located in the eastern lowlands of Ethiopia and falls in the Somali-Masai Regional Centre of Endemism (White 1983) (Fig. 1). The Sanctuary is situated at the semi-arid transboundary between Oromia and Somali Regional States at about 560 km from Addis Ababa. Its geographical position is within latitudes of $08^{o}22'30''$-$09^{o}00'30''$N and longitudes of $42^{o}01'10''$- $43^{o}05'50''$E and has an elevations range of 850 m to 1,785 m a.s.l.. When the Sanctuary was established in 1970, it covered about 6,982 km^2 (Stephenson, 1976; IUCN, 1990; Yirmed Demeke *et al*., 2006).

Four main drainage river valleys rise from Garamuleta-Harer-Gursum highlands and these extend southwards to join Wabi Shebelle River Basin. From west to east, they are the Gobele, Erer, Dakata and Fafum valleys (Fig. 2). The peak of the plateau close to the study area is Gara Muleta, which rising over 3,400 m, is the main characteristics of the Sanctuary. The gorges and valleys are formed by four rivers which all dissect the Sanctuary from north to south. Gobele and Erer Valleys comprise the highest portion of such rugged lands characterized by highly entrenched tributaries (Yirmed Demeke *et al.*, 2006).

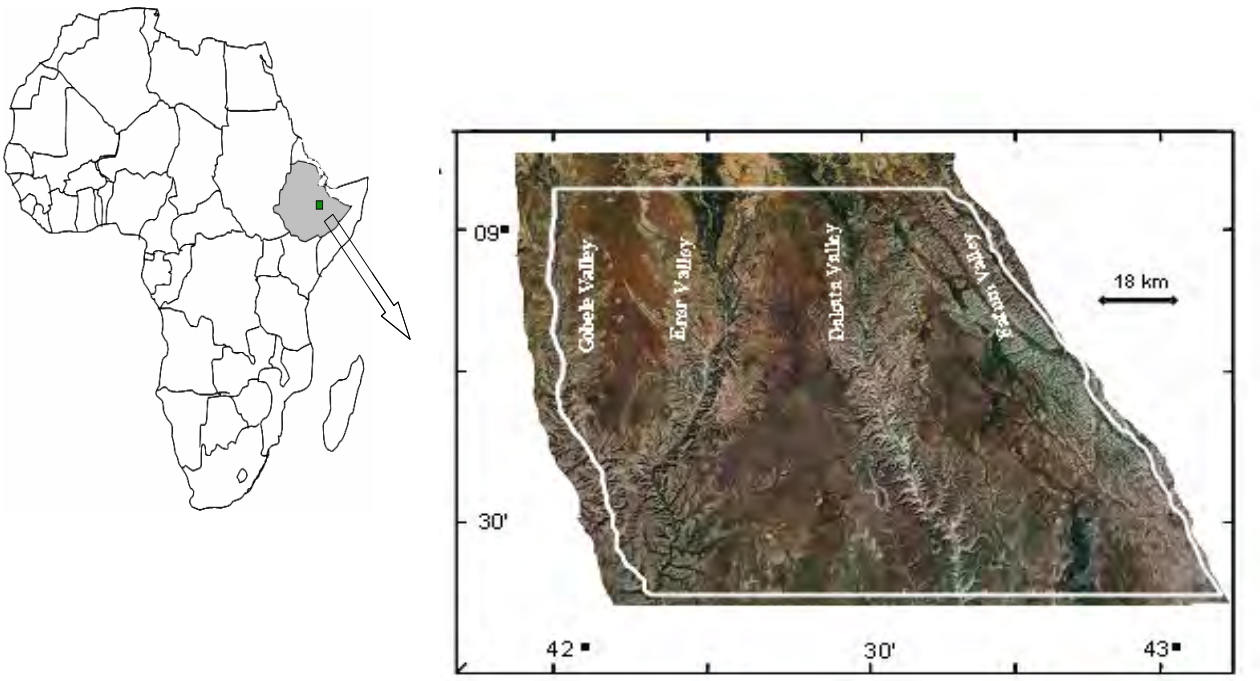


Figure 1: Location of Babile Elephant Sanctuary in east Ethiopia (Ethio GIS, 2007).

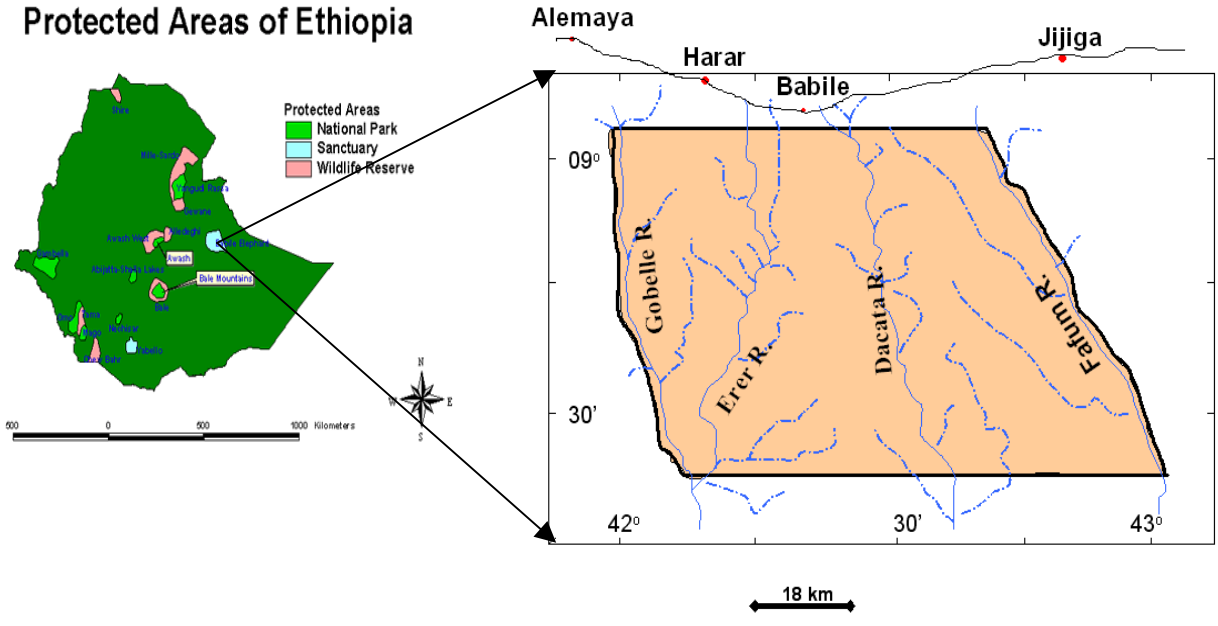


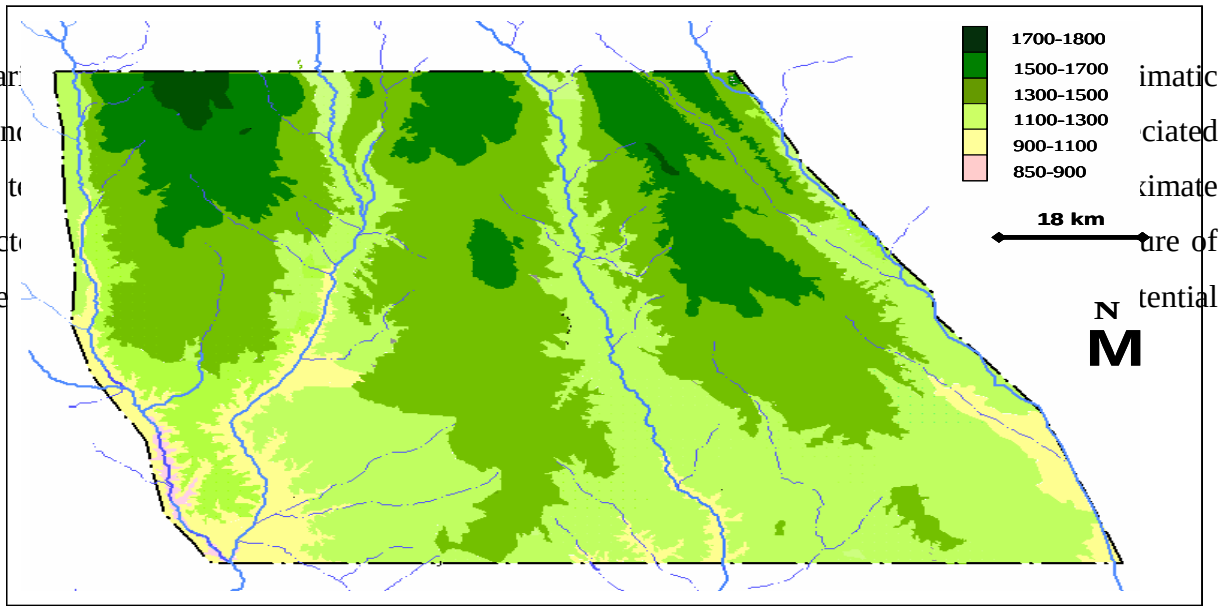
Figure 2: Drainage systems at Babile Elephant Sanctuary (Ethio GIS, 2007).

4.2. Geology and soil

The geological structure of the study area in particular and the adjacent areas in general consist of Precambrian complexes, Mesozoic-Tertiary sediments and upper Tertiary-Quaternary complexes (Mohr, 1964). The Precambrian complex underlies all recent rocks which occurred especially in the central and eastern parts of Ethiopia. The important rocks in Babile are exposures of silicate-chlorite quartzite, magnetite-quartzite and graphitic quartzite, which all are metamorphosed, and of an igneous and sedimentary origin. The younger rocks, composed of predominantly of mudstone, slaty sandstone, quartzite with black limestone and dolomite, are well exposed. In general, limestone, sandstone, gypsum, marbles and anhydrite are important geological settings (Mohr, 1964).

The physical and chemical compositions of soils are very important in determining the occurrence, growth diversity and distribution of plant species of the area. According to the information obtained from the Soil Research Department of Haromia University, Harar, (Yirmed Demeke et al., 2006) about 10%, 2% and 88% of the total area of Babile district are covered by black, clay, and clay loam soils, respectively. In general, the soil types in the study area include cambisols, luvisols, nitosols, orthic solonchakes, fluvisols, vertisols and xerosols.

4.3. Climate



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evapotranspiration. In general, the climate condition of the study area can be characterized as semi-arid and arid.

According to the Ethiopian agro-climatic classification, Babile conservation area can be grouped under 'Woinadega' (tropical rainy climate) and 'Kolla' (tropical arid climate) agro-climatic zones. The 'Kolla' agro-climatic zone consists arid and semi-arid climatic conditions. Mean monthly maximum and minimum temperatures recorded were 31.2^{o}C and 12.6^{o}C respectively (Fig. 3). The highest temperatures recorded were in the dry season from late November to mid March. December and January were the coldest months during the night.

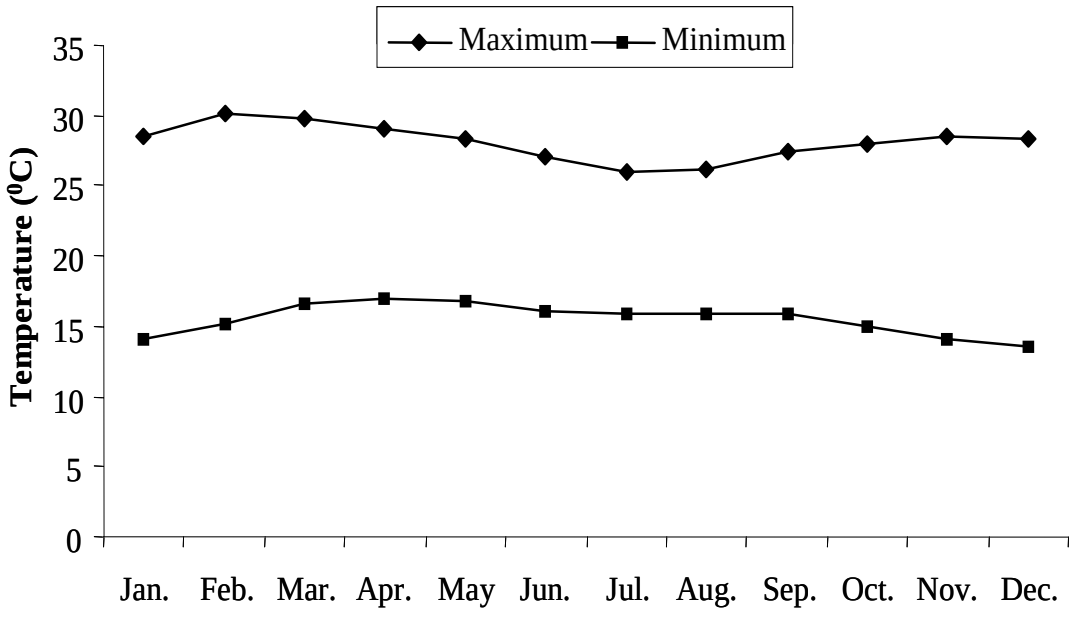


Figure 3: Mean monthly temperature data in Babile over 1995-2006 (Source; National Metrological Service Agency).

The mean annual rainfall is 702.9 mm/year, with high variation from year to year, ranging from 451.7 mm to 1,115.9 mm/year. Rainfall is bimodal occurring from March to May (short rain season) and August to November (long rain season) (Fig. 4).

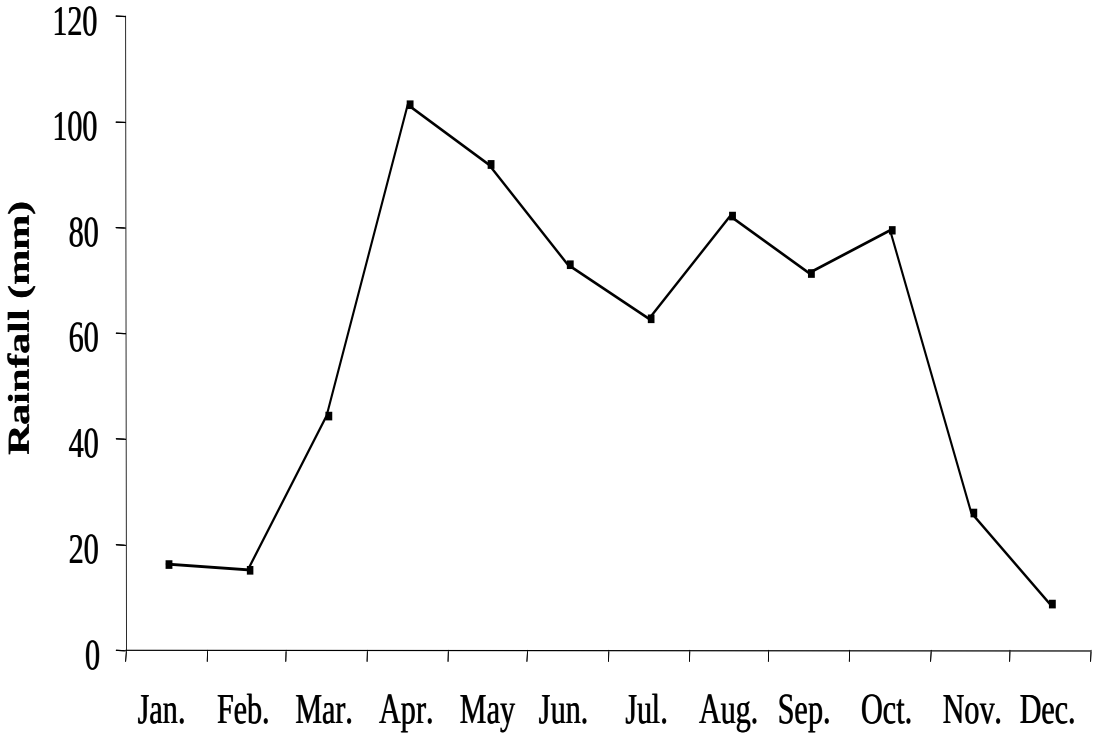


Figure 4: Mean monthly rainfall data in Babile over 1995-2006 (Source; National Metrological Service Agency).

4.4. Vegetation

In general, the Sanctuary is represented by *Acacia-commiphora* woodland, desert and semi-desert scrubland and evergreen scrub ecosystem (White, 1983; Anteneh Belayneh, 2006). The study area is a semi-arid plain surrounded by a chain of rocky hills (EHPEDO, 2004).

Generally, the vegetation of Babile is described into two major categories according to Stephenson (1976) and Yirmed Demeke *et al*. (2006).

i. Riverine vegetation: this type of vegetation has dense stand in the valley bottoms becoming sparser and poorer in composition as one progress away from the valley floors. The densest stand is found in the Upper Erer in a narrow stripe from the northern boundary to south for about 25 km. Remnants of this type of vegetation are also seen in Gobele Valley and in some areas east of Erer but with insignificant proportion (Fig. 5).

   The riverine species in both valleys is comprised of *Acacia robusta, Tamarindus indica, Oncoba spinosa, Acokanthera schimperi*, *Capparis tomentosa* and *Terminalia spinosa* (Anteneh Belayneh, 2006).

ii. Woodland vegetation: these woodlands form the major habitats for elephants and are the densest and extensive in the valley bottoms while becomes sparse and low in composition as one progresses southwards (Fig. 6). More open woodlands, which can afford cover and food for elephants, occur on the broader plateau between the Gobelle and Erer Valleys. The main tree species in Upper Dakata Valley include *Acacia tortilis, A. seyal, A. zanzibarica, Tamarindus indica* and *A. clavigera* (Demel Teketay, 1995). In the semi-arid areas drought tolerant species such as *A. mellifera* and *A. nilotica* are highly favored. Elephants use this vegetation as food when regularly crossing from one valley to the other.

Figure 5: Riverine vegetation at BES (Yirmed Demeke; November, 2006).

Figure 6: Woodland vegetations at BES (Zelalem Wodu; November, 2006).

4.5. Fauna

Reconnaissance reports indicate that the BES has diverse animal species (mammals, birds and reptiles) adapted to the semi-arid environment. The mammals of Babile were grouped into 22 species belonging to five orders and 11 families (Hillman, 1993).

The large mammal species that the Sanctuary include the African elephant *(Loxodonta africana africana)*, lion (*Panthera leo)*, leopard (*Panthera pardus)*, spotted hyaena (*Crocuta crocuta*), bat-eared fox (*Otocyon megalotis*), black and white colobus monkey (*Colobus guereza*), hamadryas baboon (*Papio hamadryas)*, aardvark (*Orycteropus afer*), Menelik's bushbuck *(Tragelaphus scriptus meneliki)*, bush pig (*Potamochoerus larvatus*), common bushbuck (*Tragelaphus scriptus*), lesser kudu (*Tragelaphus imberbis*), greater kudu (*Tragelaphus strepsiceros*), oribi (*Ourebia ourebi*) and Salt's dik-dik (*Madoqua saltiana*). Salt's dik-dik is the most numerous (Hillman, 1993; Yirmed Demeke *et al*., 2006).

Babile Elephant Sanctuary is grouped among the 73 important bird areas of Ethiopia (EWNHS, 1996). In terms of occurrence, birds are better known than other faunal groups in BES. This sanctuary supports the endemic Salvadori's serin (*Serinus salvadorii*), which is only restricted in the eastern lowlands. The Black-winged lovebird (*Agapornis taranta*) is endemic (restricted only in Ethiopia and Eritrea), which is confined to the highland vegetation in the northern section of BES (EWNHS, 1996). Generally, 191 species of birds comprising 17 orders and 51 families were documented form the Sanctuary (Hillman, 1993; Yirmed Demeke *et al*., 2006). The African rock python (*Python sebae)* and some unidentified snake species, agamas, geckos and skinks are found in BES.

4.6. Human population and land use

The total area of East Hararge zone covers 22,622.6 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. Few years back, the total human population of the zone was estimated to be 2,202,248 where male comprised 1,122,878 and female 1,079,370 (EHPEDO, 2004). 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 population size between 1990 and 1995 showed an increment by 26,541 or 47.8% (Table 1). Obviously, this population increase led to an increment for the demand of natural resources, such as arable land, water, wood for construction and energy (firewood and charcoal). It is possible that a population increment in the last five or more years that could lead to high human settlement in BES.

The majority of the population depends on crop production undertaken by rain-fed 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 papaya, guava, mango, sweet potato, tomato, and pepper are the major crops produced in the district. The land use pattern of Babile district was categorized into seven types (Table 2).

Table 1: Human population size of Babile district (Source- EHPEDO, 2004).

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

Table 2: Land use pattern of Babile district over the year 1998-2002 (Source- EHPEDO, 2004).

Land used	1998-2002	
	Area (ha)	Percent (%)
Cultivated land	17113	5.4
Cultivable land	6022	1.9
Pasture/grazing land	6655	2.1
Forest and woodland	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	316907	100

5. MATERIALS AND METHODS

5.1. Determination and quantification of elephant impact on woody plant species

A reconnaissance survey was carried out in order to identify suitable sampling sites. The preliminary observation of the study area includes assessing location, topography, habitat types and distribution patterns of elephants in the study area. Field study and data collection was carried out from a total of seven months, from September to December 2006, and from March to May 2007 after long and short rain season, respectively.

Many factors are involved when evaluating elephant impact on a specific tree species in a specific area. The areas frequented by elephants had to be identified first in order to determine which woody plants occur in that area. Savannah elephants are known to migrate according to vegetation changes (Jacobs and Biggs, 2002). Main paths are for easy and rapid travel over long distances, between favored sites while forage paths are shorter and more sinuous, running through preferred foraging sites. The elephants structure their habitats by creating a network of paths that are regularly used, either for long distance migrations, or for foraging.

Elephants of Babile exhibit a similar pattern of utilization of small patches within the background matrix of vegetation. They follow a connecting network of paths to move from patch to patch. Therefore, the network of elephant paths was used as the basis for sampling the vegetation. The majority of quantitative research on the impact of elephants on their habitat was done after noticeable changes have already taken place, or were part of long term monitoring programs. In this study the concern was on the possible impacts of elephants on woody plant species. As a result, it pertinent to concentrate on actively utilized areas.

Sample plots were located along elephant paths (Steyn and Stalmans, 2001). Line transects were established systematically and a total of 72 quadrats (20 m x 20 m size) were established. The co-ordinates of each of the plots were recorded by Global Positioning System data.

Data on woody plant species were recorded. As herbaceous layer utilization was not easily documentable and it was excluded from of this study. In each sampling plot, the diameters of all woody plants were measured by using diameter calipers. The height of trees was measured; trees above 2.5 m were visually estimated. Plants were subsequently grouped into six size classes defined by stem diameter: 0–1.9 cm (seedlings), 2–4.9 cm (small saplings), 5–9.9 cm (saplings), 10–19.9 cm (small trees), 20–29.9 cm (medium sized trees), and > 30 cm (large trees). Types of

impacts of the elephants on the woody species were noted as branch breaking, stem breaking, uprooting, felling, and bark stripping.

The impact levels were categorized as (i) no impacts by elephants, (ii) slightly impacts, if at least one main branch and few (< 50%) of side branches have been removed and (iii) severe impacts, if the tree has been uprooted, felled, its main stem has broken, 50% of the tree's bark has been stripped, or > 50% of branches removed.

5.2. Anthropogenic impacts on woody plant species

The research was conducted by the use of Participatory Rural Appraisal (PRA) technique as the main tool of data or information gathering, recommended by Martin (1995). Semi-structured questionnaires and interview was administered to members of the local community in Babile Elephant Sanctuary to gather information regarding the utilization woody plant resources. Four sampling sites were identified from the study area within which houses were randomly selected for interviews to cover at least 50% of households in each village.

For each household, and with the help of local interpreters and guides, a questionnaire was administered to the head of the household or a present adult member regarding the use of tree and plant resources. A discussion was encouraged about the issues raised in the questionnaire to obtain more insights into plant resource use and availability.

The interviews and discussions in the questionnaire were types of commonly-utilized tree and shrub plant species and their use categories, the level and frequency of utilization and quantity consumed. Further, information on whether or not useful tree and shrub resources were diminishing due to these impacts was gathered through discussions. Most of the interviews were made in the field to ensure the identity of woody plant species under question. Photographs and tape recorder were used to document information from the local informants.

5.3. Data analysis

5.3.1. Elephant impact on woody plant species

Data were captured onto a spreadsheet, using Microsoft Office Excel and Mann–Whitney U-test (Midgley *et al.*, 2005; Wiseman *et al*., 2004) and abundance, frequency and proportion of stems per species showing all impacts (classes 1–3) and those showing severe impacts (class 3) were computed. Least square regression analysis was used to quantify the relationship between abundance and incidence and ANOVA to test for significant differences between riverine vegetation and woodland areas. The overall impact level shown by each woody species in the

woodland or riverine vegetation was then calculated by adjusting for the different number of plots sampled. Population structure, density and regeneration status was analyzed using SPSS (version 14) programme. The number of plants counted was converted into density by dividing the total area sampled and the number of plants in different size categories or damage classes was expressed as a proportion of the total number counted.

Basal area is the cross-sectional area of tree or shrub stems at diameter at breast height. Generally it is the measure of dominance where the term "dominance" refers to the degree of coverage of a species as an expansion of the space that it occupies (Lamprecht, 1989), and calculated by the following formula.

$BA = \pi d^2/4$, where:

BA = Basal area in m^2 per hectare

d = diameter at breast height

$\pi = 3.14$

Importance Value Index (IVI) for woody plant species impacted by elephants was analyzed.

Importance value index = Relative density + Relative frequency + Relative dominance (Kent and cooker, 1992).

Relative density = (Number of individuals of a particular species/Number of individuals of all species under consideration) * 100

Relative frequency = (Frequency of occurrence of a particular species/Number of occurrence of all species under consideration) * 100

Relative dominance = (Basal area of a certain species/ Total basal area of all species under consideration) * 100

5.3.2. Impacts of anthropogenic on woody plant species

For the purpose of data organization and analysis, the frequency of the use and quantity of plant resources utilized, plant resource availability, relative quantities of plant resource consumed and relative categories (high, medium and low) were used. Tables were used to establish relationships between various community opinions while the Chi-squared test (Zar, 1999) was used to test for equality of responses. Multiple comparisons of percent proportions of respondents for various categories of issues were computed using ANOVA.

6. RESULTS

6.1. Impact of elephants on woody plant species

6.1.1. Population characteristics of woody plant species

Of the 55 woody plant species sampled in the riverine and woodland habitats, the impacts of elephants were recorded on 28 (50.9%) species belonging to 12 families (Fig. 7). Out of these, 13 (45.8%) were trees and 15 (54.2%) shrubs. The total density of these 28 woody plant species was found to be 11,169.3 individuals/ha where the mean density was 399. Whereas the maximum density was 3,842.7 individuals/ha (*Opuntia ficus-indica*), the minimum density 3.7 individuals/ha was recorded for *Combretum molle*. The total density of trees was 558.7 individual/ha and shrubs 10,610.6 individual/ha. Further more, shrubs have accounted for 94.9% while trees constituted only 5.1% of the total density.

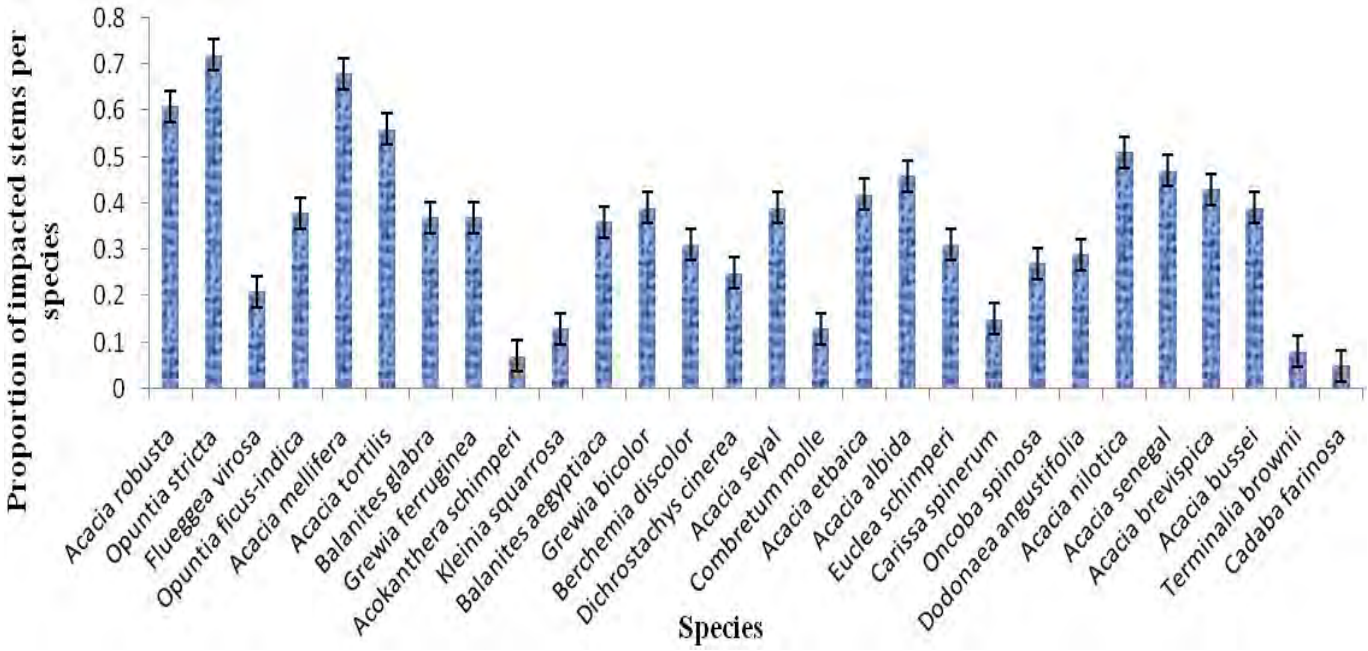


Figure 7: Woody species where the impacts of elephants were recorded at BES (original).

6.1.2. Basal area (BA) and Importance Value Indices (IVI) of woody species

The total basal area of the woody species used by elephants in the study area is 15.88 m^2/ha. The highest proportion of mean basal area was recorded for *Acacia robusta (*7.01 m^2/ha) followed by *Flueggea virosa* (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 3). These ten species accounted for 80% of the total basal area and their density is 566 individuals/ha.

Species with IVI > 10 that were under the influences of the elephants include *Acacia robusta* (IVI=41.0), *Opuntia stricta* (36.8), *Acacia brevispica* (14.9), *Flueggea virosa* (14.3), *Opuntia ficus-indica* (11.5) and *Acacia mellifera* (10.7) (Table 3). Relatively, high IVI values of these species indicate their ecological value or importance value in the study area. Most of the woody species that were under constant impacts by elephants include *Acacia tortilis* (7.2), *Acacia bussei* (8.8), *Balanites aegyptiaca* (4.0), *Berchemia discolor* (3.0), and *Acacia etbaica* (1.3) resulted in IVI < 10.

Elephants were very selective when they utilize certain plant species as well as plant parts such as roots, leaves, twigs, branches and bark. It is obvious that riverine and woodland vegetations have varied proportion and composition of species. *Acacia robusta* and *Acokanthera schimperi* are dominant tree species with significant mean cover abundance value at the riverine vegetation. Species such as *Balanites aegyptiaca, Opuntia ficus-indica, Oncoba spinosa,* and *Acacia brevispica* and *Opuntia stricta* also occur in riverine vegetation. Woodland shows a higher in relative numbers of species than riverine vegetation with *Acacia mellifera, Opuntia stricta, Grewia ferruginea, Terminalia brownii, Balanites aegyptiaca* and *Acacia nilotica* as dominant species with significant IVI.

Table 3: Important Value Indies (IVI) of the woody species impacted by elephants at BES (original).

Scientific 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 brevispica	Sh	59	2261.3	0.18	5.133	8.76	1	14.9
Flueggea virosa	sh	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 bussei	T	40	47.3	0.917	3.466	0.18	5.2	8.8
Acacia tortilis	T	36	41.3	0.702	3.120	0.16	3.9	7.2
Terminalia brownii	T	12	34.3	0.762	1.04	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
Balanites aegyptiaca	T	28	31.0	0.262	2.426	0.12	1.5	4.0
Acacia senegal	Sh	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
Cadaba farinosa	Sh	18	266.8	0.12	1.56	1.03	0.7	3.3
Berchemia discolor	T	17	15.3	0.268	1.473	0.06	1.5	3.0
Acokanthera schimperi	Sh	14	309.3	0.043	1.213	1.20	0.2	2.7
Dichrostachys cinerea	Sh	15	325.3	0.021	1.300	1.26	0.1	2.7
Acacia seyal	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 albida	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

Key: T=tree, Sh=shrub, Freq= frequency, Dens=density, ha=hectare, BA=basal area, Rfre= relative frequency, Rden= relative density, Rdom= relative dominance, IVI=Importance value index.

6.1.3. Types and intensity of impacts on woody plant species

Elephants showed a substantial influence on the vegetation structure in both habitats, i.e., riverine and woodland vegetations. Trees had evidence of bark stripping and/or branch/stem breakage by elephants. Browsing was easily recognized by a characteristically frayed appearance at the end of twigs and small branches (Fig. 8A). Debarking is linked to the action of tusking and stripping away the inner and outer layers of bark (Fig. 8B). The structural compositions of riverine woody species were more strongly associated with water distribution, and plots close to a water point were the most frequently damaged.

Figure 8: The impacts of elephants on *Acacia* species at BES. A, browsed twig of *A .mellifera* (black ring); B, debarked *A. robusta* trunk, the paler areas are exposed sapwood where the bark has been removed (Zelalem Wodu; December, 2006).

The most abundant and widely distributed species in the study area include *Acacia mellifera* and *Opuntia stricta*. Noteworthy is that less common or rare species such as *Acacia robusta, Balanites glabra, Acacia albida, Oncoba spinosa, Acacia nilotica, Grewia ferruginea*, and *Acacia etbaica* were found to have been under relatively heavy impacts of elephants. On the other hand, no impacts of elephant were recorded in 27 woody species. Some of these species are fairly common. They are *Lantana camara, Solanum incanum, Rhus natalensis, Plectranthus puberulentus, Lepidagathis calycina* and *Steganotaenia araliacea*.

Generally, woody plant species were damaged by elephants via various mechanisms, i.e., branch and stream breakage, felling, and bark stripping. Besides, there are species which were found unaffected by foraging activities of elephants. The riverine vegetation showed relatively more felled woody species (22.61%) than the woodland (18.19%). On the other hand, woodland vegetations have a higher proportion of uprooted (10.44%) trees/shrubs than riverine vegetation (5.26%). Whereas bark stripping was found to be significant in the riverine vegetation following Mann-Whitney U test (U = 0.005), both branch and stem breakage appear to follow a similar pattern in both riverine and woodland habitats (Fig. 10).

The different types of impact by elephants did not occur with equal frequency in both habitats and each of them was distributed differently, for example, in terms of size classes. The most common damage from the elephant was branch breaking, followed by stem breaking, felling and uprooting. The least frequent damage was found to be bark stripping in the study area (Fig. 9).

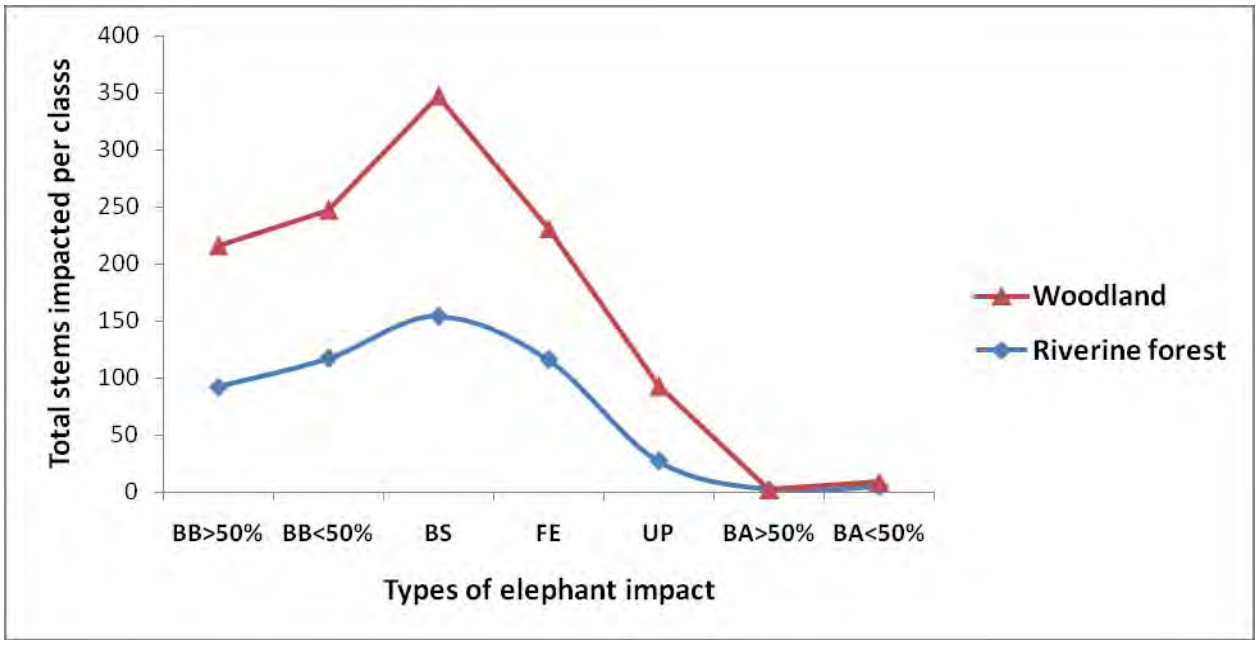


Figure 9: Types of elephant impact (BB, branch broken; BS, broken stem; FE, felled; UP, uprooted; BA, bark stripped) experienced by woody species at BES (original).

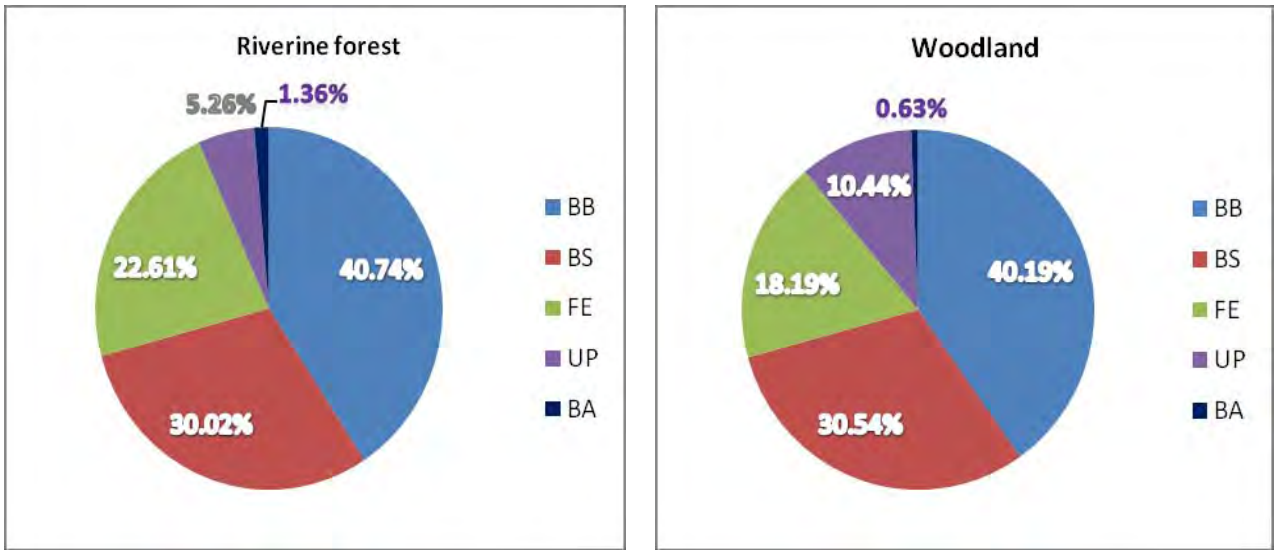


Figure 10: Types and frequency of elephant impact in the riverine and woodland vegetation at BES (BB, branch broken; BS, broken stem; FE, felled; UP, uprooted; BA, bark stripped) (original).

6.1.4. Levels of the impacts of elephant on riverine and woodland habitats

Impact levels of elephants on woody plant species did not differ between riverine and woodland habitats (Kruskal–Wallis test: for all impacts $\chi^2 = 0.443$, d.f. = 1, $P = 0.505$; for severe impacts $\chi^2 = 0.243$, d.f. = 1, $P = 0.622$). Impact levels differed among diameter size classes (log linear analysis: $\chi^2 = 72$, d.f. = 4, $P < 0.001$, for all impacts). In riverine, saplings, small trees and medium-sized trees showed higher impact levels (Fig. 11). In the woodland habitats, large, medium and small trees showed impact levels above the overall mean across all stems. Whereas, the majority of small trees and medium-sized trees had either broken stems breakage or entirely felled (Table 4) in riverine vegetation, sever impacts were primarily felling, and branch breaking in the woodland vegetation. The overall proportion of impacted woody species, ranged

from 0.05 to 0.49 for all impacts, and 0.04 to 0.45 for severe impacts following an adjusted for the relative sampling intensity.

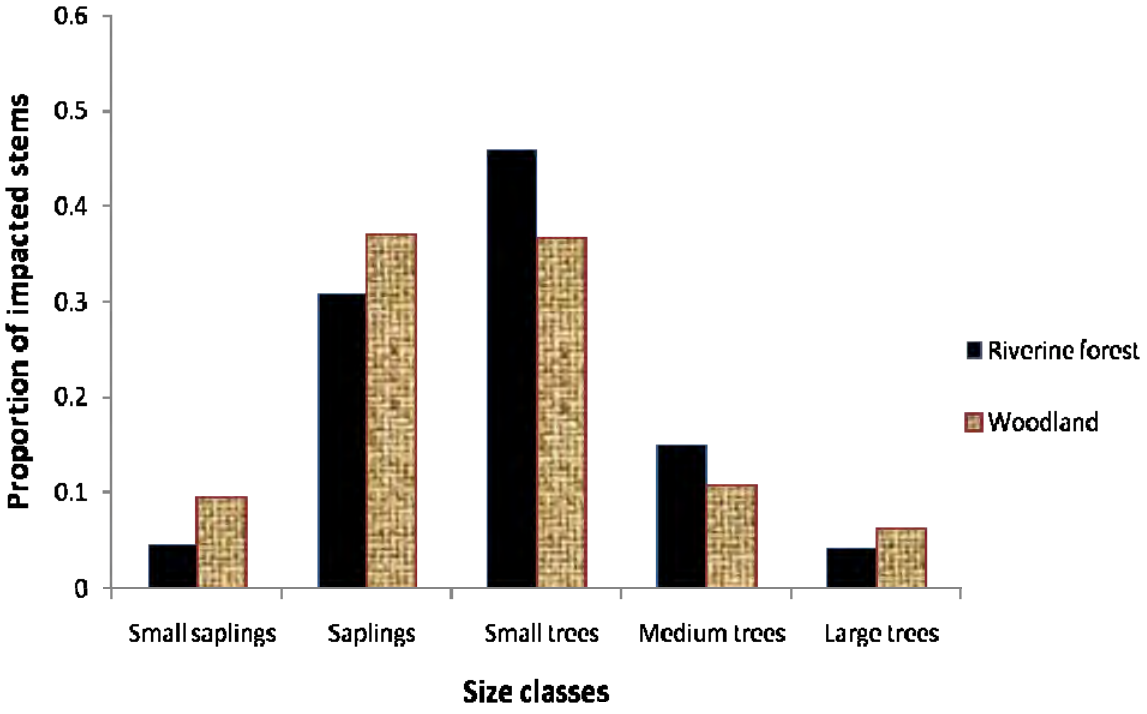


Figure 11: Proportion of impacted stems per diameter size class per vegetation type by elephants (original).

Table 4: Types of elephant impacts on woody species according to size classes (number in parenthesis are total number of impacted species) (original).

Size classes	Total stems sampled per class	Total stems impacted per class	BB>50%	BB<50%	BS	FE	UP	BA>50%	BA<50%
a: Riverine forest									

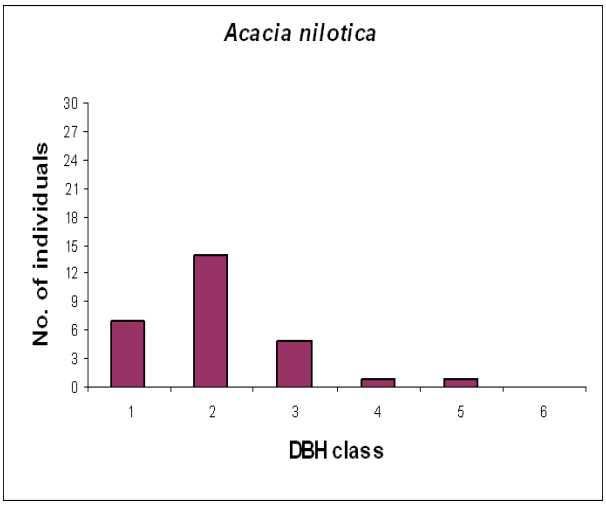
Seedlings	34	-	-	-	-	-	-	-	-
Small saplings	337	23	0.3 (1)	1.5 (5)	3.3 (11)	1.5 (5)	0.3 (1)	-	-
Saplings	615	158	3.6 (22)	6.7 (41)	9.9 (61)	2.3 (14)	2.6 (16)	-	0.65 (4)
Small trees	545	235	9.3 (51)	9.5 (52)	11.4 (62)	11 (60)	1.8 (10)	-	-
Medium trees	227	76	4.8 (11)	7 (16)	8.4 (19)	12.8 (29)	-	-	0.44 (1)
Large trees	97	21	7.2 (7)	3.1 (3)	1.0 (1)	8.2 (8)	-	2.1 (2)	-
Total	1855	513	5 (92)	6.3 (117)	8.3 (154)	6.3 (116)	1.5 (27)	0.1 (2)	0.3 (5)
b: Woodland									
Seedlings	114	-	-	-	-	-	-	-	-
Small saplings	629	60	1.1 (7)	1.4 (9)	2.5 (16)	0.2 (1)	4.3 (27)	-	-
Saplings	1028	234	3.4 (35)	5.1 (52)	9.8 (101)	1.6 (16)	2.9 (30)	-	-
Small trees	711	231	7.7 (55)	6.5 (46)	7.7 (55)	9.1 (65)	1.1 (8)	-	0.3 (2)
Medium tress	195	68	9.2 (18)	6.7 (13)	8.7 (17)	9.7 (19)	0.5 (1)	-	-

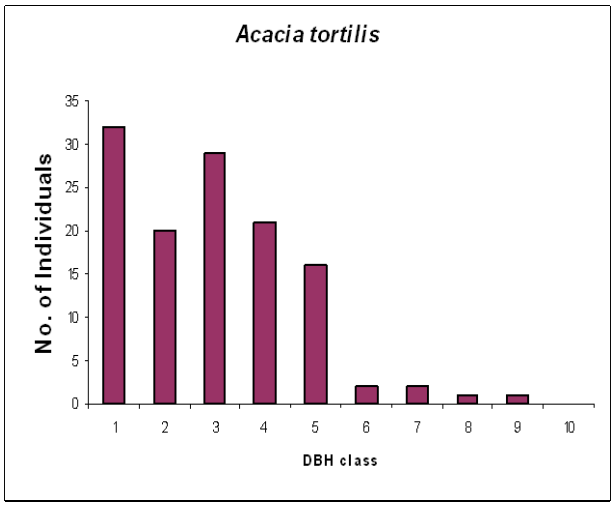
Large trees	95	39	9.5 (9)	10.5 (10)	4.2 (4)	14.7 (14)	-	-	2.1 (2)
Total	2772	632	4.5 (124)	4.7 (130)	6.96 (193)	4.14 (115)	2.3 (66)	-	0.1 (4)

Key: BB, branch broken; BS, broken stem; FE, felled; UP, uprooted; BA, bark stripped.

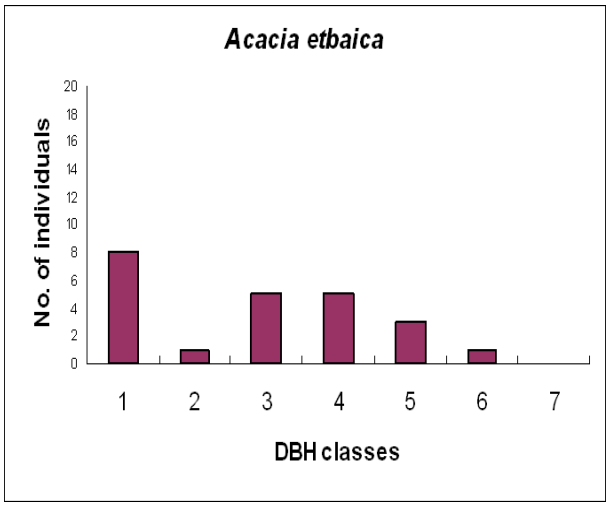
6.1.5. The impacts of elephant on the population structure of dominant woody species

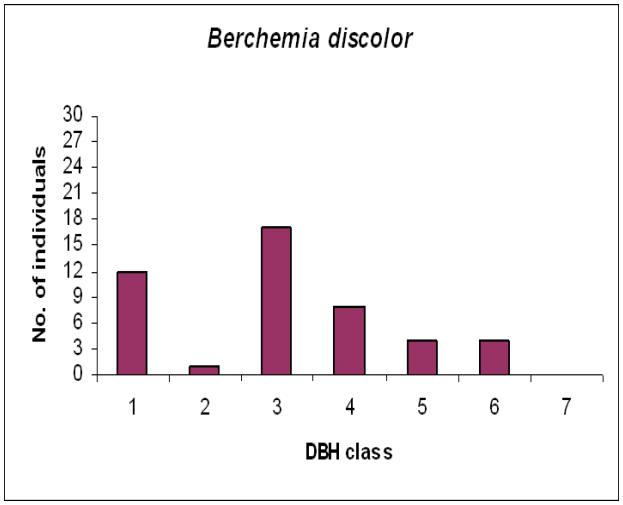
The population structure of woody plant species impacted by elephants exhibited broken inverted J-shaped (*Acacia nilotica*), U-shaped (*Acacia robusta)*, broken inverted J-shaped (*Berchemia discolor*) and bell-shaped (*Balanites aegyptiaca*) frequency distribution (Fig. 12).



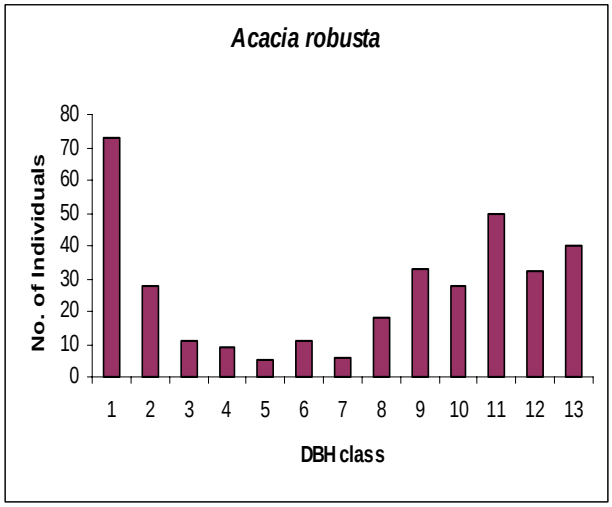


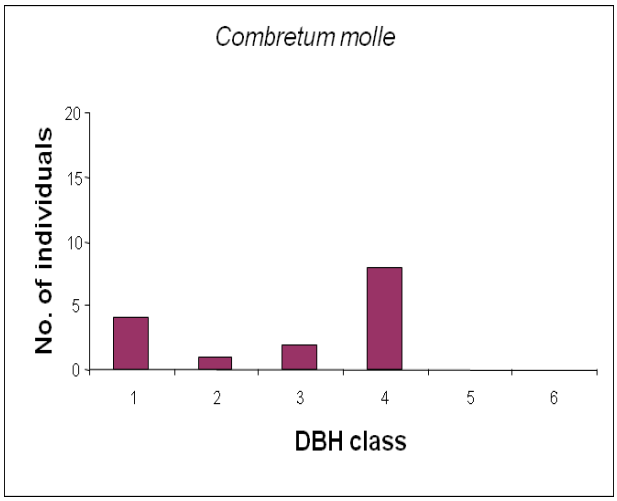
a) Inverted J-shaped



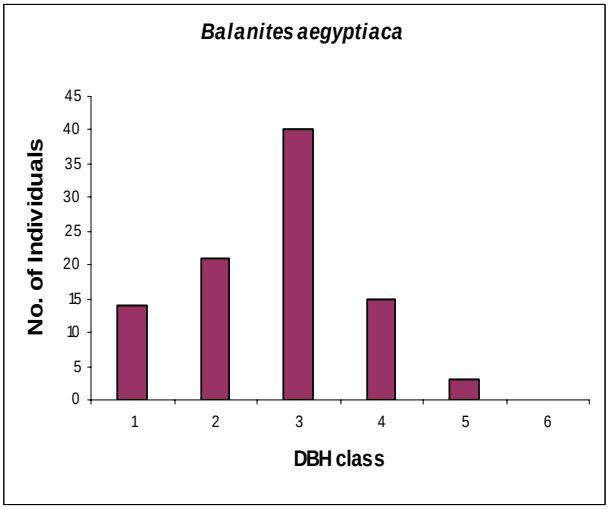


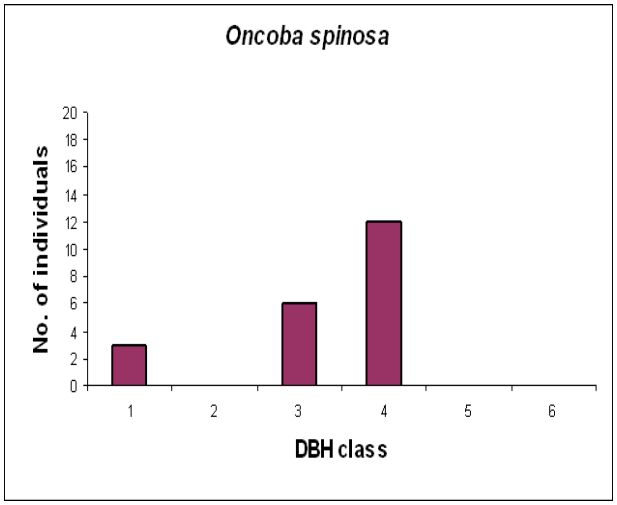
b) Broken inverted J-shaped





c) U-shaped





d) Bell-shaped

Figure 12: Population structure of some woody plant species impacted by elephants at BES (original).

6.1.6. Regeneration status of woody plant species as the function of the impacts of elephants

Analysis of result showed different regeneration potential between individual species. The total density of seedlings, small saplings, and saplings of these woody species was 3377 individuals/ha. Top selected trees like *Acacia robusta* (47 individuals/ha), *Balanites aegyptiaca* (17 individuals/ha), *B. glabra* (24 individuals/ha) and *Acacia tortilis* (18 individuals/ha) showed relatively better regeneration among the tree species. Among the shrub species *Acacia mellifera* (342 individuals/ha), *Dichrostachis cinerea* (112 individuals/ha), *Grewia ferruginea* (112 individuals/ha) and *Grewia bicolor* (96 individuals/ ha) showed better regeneration than other the species (Fig. 13 and 14).

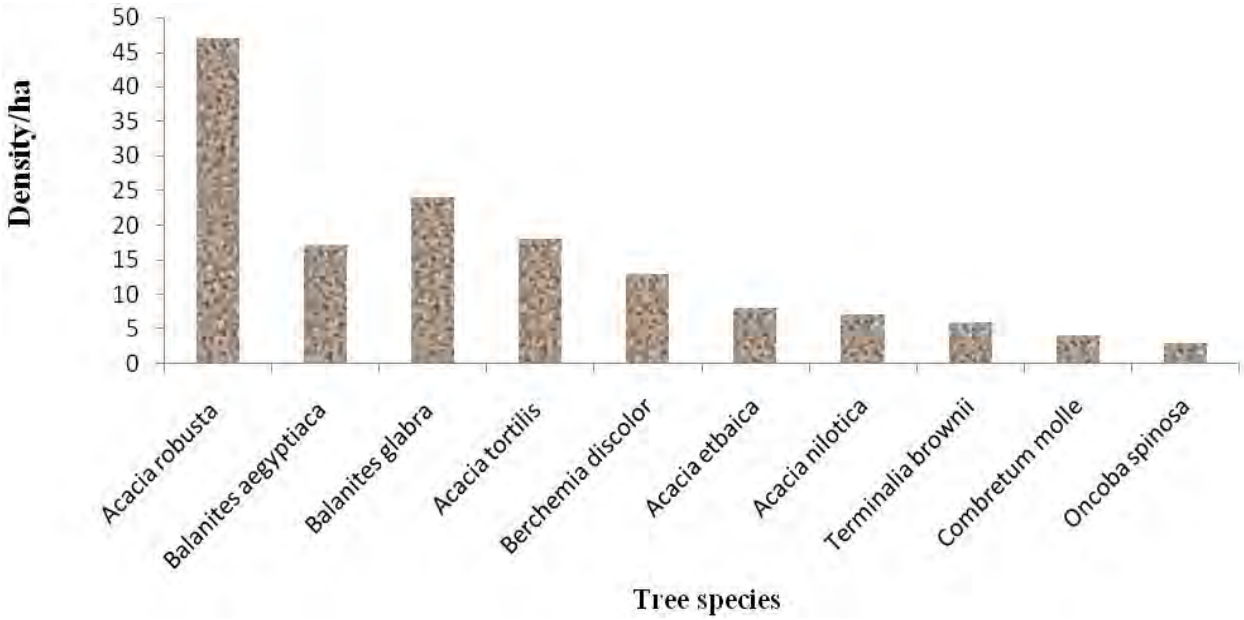


Figure 13: Regeneration density per hectare for the most impacted tree species (original).

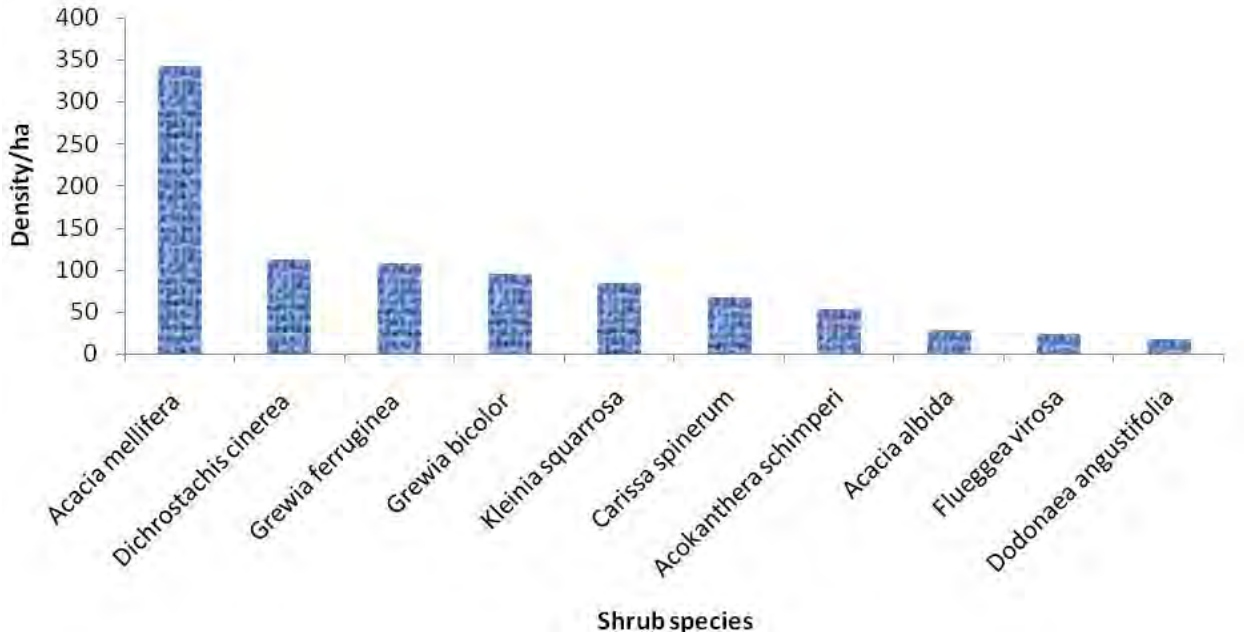


Figure 14: Regeneration density per hectare among the most impacted shrub species (original).

6.2. Anthropogenic impacts on woody plant species

6.2.1. Utilization of riverine and woodland resources

Analysis of result showed that between 95 and 100% of the local community interviewed used woody plant products in one way or another, at varying degrees. Only 9% of the households are engaged in the sale of collected woody plant products. They sell these products through market or roadside stalls. Harvesting of trees and shrubs for ethno-medicinal purposes was the most commonly identified form of use (18 ± 4% of respondents across species from), followed by fencing (13 ± 5% of respondents), firewood (8 ± 3% of respondents), and lastly construction of homesteads (4 ± 3% of respondents) (Tables 5 and 6). However, the proportion of people for various uses did not differ from each other ($F = 2.36$; $df = 3, 68$; $P = 0.08$). The uses of tree and shrub species were found to be species-dependent (Chi–squared contingency table, $\chi 2 = 146.27$, $df = 24$, $P < 0.001$).

Some of the important species and their main uses are *Acacia mellifera* (used for fencing, firewood, building and medicinal purposes), *Balanites glabra* (for medicinal purposes, fencing and building), *Acacia tortilis* (fencing and firewood) and *Acacia seyal* (fencing and firewood). Other important, multiple purpose tree and shrub species include *Acacia robusta, Acacia senegal, Commiphora erythraea,* and *Acacia nilotica.*

Table 5: Tree and shrub species commonly used by the local community of Babile Elephant Sanctuary (original).

Species	Purposes of use (%)				Frequency of utilization (%)			Quantity utilized (%)		
	Building	**Fencing**	**Fuelwood**	**Medicinal**	**High**	**Medium**	**Low**	**High**	**Medium**	**Low**
Acacia mellifera	46	76	49	32	74	16	7	80	9	4
Balanites glabra	17	42	14	60	26	34	10	24	25	25
Acacia tortilis	7	54	32	7	37	31	6	40	21	13
Acacia seyal	3	19	16	4	4	17	10	5	12	13
Acacia robusta	1	6	6	7	1	9	6	2	7	4
Commiphora erythraea	0	7	2	10	3	8	9	6	0	10
Grewia bicolor	8	0	2	1	2	5	3	4	3	4
Grewia tenax	2	0	1	0	2	4	0	1	1	0
Acacia bussei	0	8	2	16	6	10	4	8	5	8
Acacia albida	0	1	10	7	6	7	3	4	1	8
Salvadora persica	0	0	0	48	17	24	9	14	14	10
Balanites aegyptiaca	4	14	4	31	18	13	3	15	14	6
Acacia nilotica	1	7	3	13	2	11	2	4	5	4

Terminalia brownii	0	3	2	31	7	10	17	11	5	19
Ziziphus spina-christi	0	1	0	13	7	7	7	3	5	12
Sterculia africana	1	0	0	17	3	11	4	3	6	6
Opuntia ficus-indica	0	0	1	9	1	3	2	3	1	5
Comberatum molle	0	0	0	12	8	2	1	9	0	2

6.2.2. Frequency and intensity of utilization of woody plant species

Fuelwood was collected on a weekly basis in many householders. Poles were only gathered when needed, usually once a year to replace those that have become decayed over the past year. Harvesting of medicinal plants is also done on a regular basis, but generally limited to a few women who know the species. Wild foods are collected and hunted for local consumption. Apart from *A. mellifera*, *A. tortilis* and *B. glabra* which have a high frequency of utilization, all other species were used at relatively low and almost similar frequencies (Table 5). However, the frequency of use of trees and shrubs of the 'high' use category (13 ± 4% of respondents across species) was the most commonly identified, followed by 'medium' frequency of use (12 ± 2%), and lastly 'low' frequency of use (6 ± 1%).

The proportion of people identifying the various levels of frequency of use did not differ from each other (Table 6). The frequency of utilization of trees and shrubs was also dependent on species ($\chi 2 = 112.92$, df = 24, $P < 0.001$). The majority of the people identified high quantities of plants used for fuelewood (97%), followed by fencing purposes (77%), construction of houses (59%) and a few for medicinal purposes.

On the quantities of utilization of various plants identified by the local community, overall quantities used were generally low except for *A. mellifera*, *A. tortilis* and *B. glabra*. The majority of respondents (13 ± 5%) indicated trees and shrubs utilized by the local community as in the 'high' category, followed by the 'low' category (9 ± 2%), and lastly the 'medium' category of quantities used (7 ± 2%).

Table 6: Relative quantities of woody plant resources utilized across the four main purposes of use by the local community (original).

Purpose for which woody species used	**Relative quantities Utilized**			**No. households**
	High	**Medium**	**Low**	
Fencing of home, farms and livestock holding	7%	5%	18%	97
Fuelwood use	97%	1%	2%	94
Traditional medicinal purposes	37%	33%	30%	94
Construction of houses	59%	16%	25%	93
Mean percent of quantity of use across categories (Mean ± SE)	68 ± 13%	14 ± 7%	19 ± 0%	

6.2.3. Local perceptions for the depletion woody species cover

A significant majority of households (84%) noted that charcoal burning at the BES was for sale undertaking, while 16% of them attributed it to local household. The commonly targeted species for charcoal burning were *Acacia tortilis* (61% of the interviewees), *A. mellifera* (18%), *Balanites glabra* (13%) and *A. senegal* (8%).

A significant majority of respondents (83%) indicated that severe loss of tree and shrub cover had occurred on the Sanctuary during the past 5-10 years, compared to those who did not see such a loss (17%). Among the inhabitants, 52% households indicated that charcoal burning was responsible for depletion of tree and shrub cover at the Sanctuary.

Agricultural expansion was mentioned by 45% of the households, while fencing of home or livestock sheds was considered to be a causal factor for decline by 32% of the surveyed households (Fig. 15 and 16). Other minor factors thought to be responsible for diminishing woody plant resources of the study area include a general increase in human population (27%), harvesting plants for fuelwood (19%), climatic changes such as frequent droughts (23%) and the destructive effects of elephants (8%).

Figure 15: Fire clearing of woodlands by humans at BES (Zelalem Wodu; April, 2007).

Figure 16: Woody plant species cut by humans at BES (Zelalem Wodu; April, 2007).

7. DISCUSSION

7.1. Impact of elephant on woody plant species

7.1.1. Population characteristics of impacted woody plant species

Consequences of the feeding and foraging behavior of elephant populations are important for woody species, especially when developing conservation management options (Wiseman *et al*., 2004). Elephants spend 16 hours a day feeding, with peaks in the morning, afternoon, and around midnight. An elephant's diet requirement is usually met by forest-edge and woodland, and these habitats also provide the elephants with valuable shades (Croze, 1974). Elephant damage was not randomly distributed for riverine and woodland and habitats in Babile Elephant Sanctuary. Shrubs accounted for 94.9% of the total density of the 28 woody species impacted by elephants whereas trees only 5.1%. This is because shrubs are the dominant components of the floristic composition of the study area. As elephants prefer trees to shrubs (Croze, 1976), meeting the high feed demand of elephants of the BES could be a future challenge (cf. Appendix 4).

As many uncommon species were less frequently impacted than some of the more abundant species, any change in woody vegetation composition that might result from these impacts is likely to benefit species diversity in BES. Elephants are known to be physical ecosystem engineers with an ability to directly or indirectly control the availability of resources to other organisms (Cowling and Kerley, 2002). Pamo and Tchamba (2001) have also shown that elephants have varied effects on the vegetation; they can cause detrimental changes to some species, at the same time increasing the abundance of other species. Whitehouse and Schoeman (2003) found that elephant foraging resulted in the reduction of plant biomass and abundance at Serengeti National Park. However, Midgley *et al*. (2005) contradicted these results by showing that the density of woody plants in the Addo Elephant National Park increased with elephant

defoliation and attributed this to the fact that the removal of the canopy allows for coppicing to occur.

In both of the riverine and woodland habitat types, the frequency of elephant damage varied according to the woody plant species and size classes. Density was calculated for woody species impacted by elephants, by calculating the average individual tree and shrubs, in terms of the number of individuals per hectare in both areas (Table 3). The highest density of shrubs is due to the domination of small sized shrubs in the floristic composition in both communities. *Opuntia stricta, Acacia brevispica, Kleinia squarrosa* and *Acacia mellifera* constitute about 50% of the total density. The most probable reason for the domination of these species may be specialization of the different species to different dispersal agents. Wind can carry light seeds with thin cotyledons, e.g. *Acacia mellifera* for a considerable distance (Tybrik, 1991). Some of the plant species may have a wide range of dispersal mechanisms and/or rapid reduction strategies. Cowling and Kerley (2002) also suggested that since most of the shrubs produce bird-dispersed fruits, they are able to recolonize areas successfully.

The relative importance value of each species was determined in each of the vegetation groups by using a composite of frequency of occurrences and distribution across cover classes in each plot, and by comparing this with the actual utilization of these different species. Preferred and selected species were identified. Proportional impact, specific plant parts, as well as the main type of impact per species was observed. Three main categories of impacted species could be distinguished. In the first category, woody species are fairly common in occurrence, frequency and cover. Their utilization is also high. It can thus be concluded that there is no special selection in terms of preference, but elephants rather utilized them due to availability. Species such as *Acacia nilotica, Dodonaea angustifolia, Acacia bussei, Balanites aegyptiaca* and *Acacia tortilis* included in this category. The utilization of these species was proportionally between 25 and 65%. Guy (1976) also determined that elephants utilize certain species according to their availability and frequency. The second category contains the species that show low utilization and high importance. They are abundant, but not preferred species; *Opuntia ficus-indica* and

Flueggea virosa included under this group. Although their utilization rating was low, the proportional utilization is still nearly 50%. The type of utilization is mainly in the bark stripping category. Guy (1976) and Cowling *et al*. (2002) found that certain plant species that occurred in relative high frequencies in a study area are not utilized at all.

The third category represented those species with high utilization and low importance values. These species such as *Acacia nilotica, Grewia bicolor, Balanites aegyptiaca* and *Acacia tortilis* occurred in low numbers, but were actively selected by the elephants. Elephants showed a disproportionate selection by more than 70% for these species, and in some instances closer to 100%. They were widespread, but in low numbers and where they occurred in the sample plots, they were utilized to an extent that they die off. Meseret Ademasu (2006) found that elephant has a preference for certain plant species, while showing a distinct dislike for others.

7.1.2. Basal area (BA) and Importance Value Indices (IVI) of woody species

The total basal area of the woody species impacted by elephants in the study area is 15.88 m^2/ha. Species dominance implies the basal area per ha coverage of each individual woody species. About 80% of the dominance was accounted for ten woody plant species. These woody species are the top impacted by elephants as well as multi purpose function for the local communities. Perhaps it is due to their relatively high dominance value in the Sanctuary that these species had a high feed demand of elephants and the local community consumption. However, if the current anthropogenic threat on these woody species continues, their density will decrease down, and then their dominance may not be able to support the highest feed demand for the resident elephants (Anteneh Belayneh, 2006).

Species importance value index is a function of basal area of the woody species and it reflects the dominance of species in an area (Kent and Cooker, 1992), and basal area is the area of the cross section of a tree trunk near its base, usually 1.4 m above the ground. It is a way to measure

how much of a site is occupied by trees (Lamprecht, 1989). The importance value index (IVI) is useful to compare the ecological significance of species (Lamprecht, 1989). Trees and shrubs with IVI>10 can be considered as the most important species at BES since they have efficient seed production and dispersal system to colonize a wide range of areas (Mekuria Aragaw *et al*., 1999).

Even if *Acacia robusta* has high IVI (Table 3), the population structure (Figure 11) showed that these tree species had U-shaped pattern that indicating selective removal of medium sized trees. Woody plant species such as *Acacia tortilis, Acacia bussei, Balanites aegyptiaca, Berchemia discolor,* and *Acacia etbaica* had IVI<10. Their lower IVI may indicate that these woody species are threatened and in need of immediate conservation measure. Selective harvesting contributes to less IVI as it reduces the total basal of the species.

7.1.3. Types and intensity of impacts on woody plant species

In both habitat types, the frequency of elephant damage varied according to woody plant species and size classes. The proportion of woody plants utilized by elephants increased with the proximity to water sources. These two factors also affected the probability of severe damage in the riverine savanna whereas in the woodland only the effect of tree size class was significant. Many factors are involved when evaluating elephant impact on a specific woody plant species in a specific area (Hiscocks, 1999). Studies from other riverine woodland habitats where large shrubs and trees are abundant suggest that elephants primarily affect the size structure of woody plant populations (Osborn, 2004).

The difference in the densities of impacted woody species between the riverine vegetation and woodlands may be attributed to the difference in the size of woody plant species in these habitat types. Large sized trees and shrubs were recorded from the riverine habitat that may decrease the density. Medium sized woody species were recorded from woodlands where most tree species lost high DBH classes due to exploitation, resulting in low density. Therefore, the

woodland habitat is dominated by small sized woody plant species that contributed for the highest density of individual per hectare.

The least density of the most important woody species such as *Oncoba spinosa, Acacia etbaica, Salvadora persica, Dodonaea angustifolia* and *Acacia nilotica* showed how these species are highly threatened in the study area. Croze (1974) found elephant utilization of species size classes in the Serengeti, Tanzania, was in proportion to availability.

In the prsent study, trees in the larger size classes tended to be debarked, whereas the smaller trees were browsed. Trees that were heavily browsed were found to be extremely bushy around the trunk and were rarely debarked (Fig. 17). Taken together, and in conjunction with field observations, these results suggested that the bushiness induced by browsing may afford some protection to the tree.

Figure 17: Picture sowing bushy *Acacia etbaica* (note the trunk is obscured) (Zelalem Wodu; December, 2006).

In sampling plots of both habitats, this study found that elephants selected short trees. Larger woody plant species were also frequently damaged, but they often presented severe damage (Fig. 8 and Table 4). Owen-Smith (1988) noted that the maximum feeding reach of the elephant with the trunk is more than 6 m. The results also showed that taller trees may be pushed over, bringing higher branches within reach. Previous studies also reported that elephants prefer feeding on small trees 2–3 m in height (equivalent to small saplings and saplings in this study), thereby potentially inhibiting recruitment (Jackman and Bell, 1985).

Analysis of the result showed elephants at BES did not frequently consume small woody species in both the riverine and woodland vegetations. In the riverine, the majority of small trees and medium-sized trees were impacted by either stem breakage or felling (Table 4). In the woodland vegetation, severe impacts involved primarily felling, or branch breaking. Small trees did not have much bark or branch biomass available per tree, and consequently did not suffer from bark removal nor branch breakage. Attempts at bark or branch removal probably resulted in main stem breakage, but the low levels of any damage on the smallest classes indicated that they were not selectively fed upon. Both in the riverine and woodland habitats, woody plant species were impacted according to size with smaller trees less impacted than the taller trees. Trollope *et al.* (1998) also determined that elephants show a preference for uprooting large mature trees. A species-specific impact study by Hiscocks (1999) in the Punda Maria area demonstrates the different ways in which elephants utilize knobthorn trees of different age classes. Virtually all younger adult trees were pushed over but hardly used at all, probably because of the protection rendered to the main stem by the many thorny branches. Determining the levels of damage can therefore be looked at as primarily involving this group of plants. The type of elephant impact on the species did not necessarily cause mortalities. It can induce secondary infections that eventually kill the species.

7.1.4. Population structure of dominant impacted woody plant species

Out of the most selected woody plant species by elephants, *Acacia tortilis, Acacia nilotica, Acacia etbaica, Balanites aegyptiaca, Berchemia discolor, Oncoba spinosa* and *Salvadora persica* were highly threatened and they account only 1.4% of the total density. Preferentially utilized trees include those that provide shade or fruit such as *Acacia* species (Barnes 1983), nutrients – such as calcium and nitrogen, and those individuals that are more exposed or accessible (Pamo and Tchamba 2001). 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. Survival and regeneration is common where some of the bark (Mwalyosi, 1987) or root system (Croze, 1974) remains intact. Furthermore, browsing can stimulate rapid regrowth by reducing inter-shoot competition for nutrients, for example Mwalyosi (1990) records 59.7 cm annual growth of elephant- utilized *Acacia tortilis*.

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 local people. Broken J-shaped (*Oncoba spinosa)* may indicate poor regeneration and selective removal, U-shaped (*Acacia robusta* and *Salvadora persica*) 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 suggest poor regeneration and recruitment in the lower class and selective/exploitation of the bigger DBH classes. Due to the slow regeneration rate and low resilience, some woody plant species are believed to be extremely vulnerable to large browsers (e.g. elephant, rhinoceros and kudu) (Whitehouse and Schoeman, 2003).

Even if the results of this study showed more destruction on the tree species, the resident elephants may not be responsible for this destruction because most of these woody plant species have 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 engaging in social displays (Guys, 1976).

7.1.5. Regeneration status of impacted woody plant species

When considering changes in the vegetation due to impact by elephants the most important step would be to determine whether recruitment by surviving saplings and seedlings can maintain the tree population (Owen-Smith, 1988). The difference in recruitment rate may be brought about by many factors such as biological, climatic, soil and anthropogenic factors. As sated 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 total regeneration of woody species selected by elephants shows that shrubs dominate the regeneration process. The least regeneration count for tree species such as *Oncoba spinosa, Acacia nilotica, Salvadora persica* 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. Fire and grazing have also greater effect on seedling, saplings and lower diameter class trees (Tybrik, 1991).

Highly level of impacts on tress such as *Acacia robusta, Balanites aegyptiaca, B. glabra* and *A. tortilis* could be attributed to the density of mature trees, presence of substantial amount of viable seeds in the soil and wide dispersal of seeds through ungulate faeces. The number of germinating seeds depends on availability, seed quality and germinating condition (Nellemann *et al*., 2002). In the study area, about 95% of the regeneration was recorded for shrubs. This result may show that the natural vegetation in the BES is moving towards shrubland/bushland since the population of tree is declining.

7.2. Anthropogenic impacts on woody plant species

7.2.1. Use of riverine and woodland resources

Woody plant species such as *Acacia mellifera, Acacia tortillis, Balanites glabra* and *Acacia senegal* were used for a variety of purposes in relatively large quantities and at higher frequencies. These species are relatively widespread at Babile Elephant Sanctuary. They represent some of the dominant and large woody plants on the sanctuary, the branches, bark, leaves and trunks of which can be used for a variety of purposes and in satisfactory quantities. Even though they are used in relatively larger quantities, these plant species are still considered relatively available. This is because they are characterized by relatively large basal and crown cover and once the saplings grow fast beyond the browsing range of the local livestock, while their thorns discourage browsing by a variety of free-ranging domestic and wild ungulates that inhabit the rangelands (Mbuya *et al*., 1994).

The sapling *Acacia mellifera* is characterized by large multiple-stem stands, they easily out-competes other plant species, to the extent of dominating most of the landscape. It successfully colonizes degraded soils and sites due to its natural ability to fix atmospheric nitrogen, which is a limiting nutrient in such soils (ICRAF 1992, Moore *et al*. 1998). This species was also preferred because of its durability and high wood density. *A. mellifera* has the ability to recover quickly, especially if only the crown is harvested, and has short seed germination duration of 2–14 days and 50–80% seed viability (Mekuria Aragaw *et al*., 1999). *Balanites glabra* is also successful in the BES, partly because of its ability to survive in the alkaline soils (Brady and Weil, 1999). A large crown dominates the growth form of *Acacia tortilis,* with a deep and widespread root system which enables it to access water in the lower strata of the soil horizon. These potentially increase its ability to withstand dryland conditions. Its pods are widely consumed by a variety of domestic and wild herbivores, which facilitates the breaking of seed dormancy as well as enhancing germination rate and promoting high seed dispersal (Ensermu Kelbessa *et al*, 1992).

7.2.2. Frequency and intensity of utilization

Analysis of results showed that despite medicinal uses being a more frequent purpose, the plant was also characterized by a relatively high frequency of use and in low quantities. This is expected considering the socio-economic and practical use dynamics of ethnomedicinal resources among the local people in the Sanctuary (Anteneh Belayneh, 2006). Given their high level of poverty with a majority living in remote areas away from modern medical facilities and adhering to their traditional lifestyle, they rely mostly on these plant resources for their medical needs (Mekuria Aragaw *et al*., 1999). Most plants are used for one or more types of illness and different parts of a plant are used, especially roots, barks and leaves. This explains why medicinal use was mentioned relatively more frequently and across most plant species than any other use.

Fencing was the second most common use and this could be attributed to the traditional and cultural fencing practices among the local community. They use plants, particularly thorny species like *Acacia mellifera, A. tortilis* and *Balanites glabra*, to fence off homes and livestock sheds. Such fences are replaced periodically with new plant materials to sustain their effectiveness once they start weathering and decomposing. A single home depending on its size and livestock herd, may consume large amount of preferred plants for fencing. As human and livestock populations in the Sanctuary increase, a potentially high demand and consumption of plants for fencing can occur. Since fencing needs relatively high quantities of plant materials and needs periodic replacement, this could account for the second highest amount of plant resources used after firewood use. Most rural communities in Ethiopia, including the people of BES, use wood fuel to provide for daily energy needs such as cooking and home heating. Plants that are used for these purposes must be readily available to meet the daily needs, have high fuel output and be available in sufficient quantities. This can perhaps explain why local communities in BES indicated that plant resources used for firewood consume the largest quantity.

Uses of plant resources for construction of home was the least in terms of plant resource usefulness simply because this requires durable woody plants and thus replacement or movement of homes takes longer, probably not less than 15 years. *A. mellifera* and *B. glabra* species are commonly used for construction purposes because they mainly supply the poles and support for home structures, with additional reinforcement by other plants, especially *Grewia bicolor* and *A. tortilis* branches (Azene Bekele *et al*., 1993).

7.2.3. Local perceptions on the factor for the depletion woody species cover

This study finding showed that most local communities have noted and are concerned about is the decline in the overall tree and shrub cover. This potential depletion could be due to a combination of factors such as expansion of agriculture, increased human settlements, livestock overgrazing and an overall increased demand on plant resources for various purposes. Other possible factors are frequent drought in the recent past and, to a small extent, damage of trees by elephants from adjoining protected areas. However, more research is needed to establish the actual field abundance and availability of these plant resources, and the relative contribution of these factors to the decline of tree and shrub cover in this communal pastoral rangeland. One particularly serious threat is increasing incidences of charcoal burning, especially targeting the key species such as *A. mellifera*, *A. tortilis* and *A. senegal*.

Charcoal burning has increased in the Sanctuary, especially for commercial purposes. This could be due to increased demand for this form of fuel in urban areas like Harar and Diredewa, as well as upcoming nearby market centers at Babile town. Charcoal burning results the destruction of native plants to enable the local people to generate alternative revenue to their declining pastoral lifestyles (Anteneh Belayneh, 2006).

8. CONCLUSIONS AND RECOMMENDATIONS

8.1. Conclusions

The present study shows that even a very low density of elephants can have surprisingly great impacts on woody plant species. Nevertheless, the current level of elephant impacts on woody vegetation does not seem to threaten the species diversity at this stage.

Elephant damage was not randomly distributed on riverine and woodland habitats. In both habitat types, the frequency of elephant damage varied according to woody species and size class; these two factors were also affecting the probability of severe damage. Smaller circumference trees were generally the most damaged as an elephant removes the same amount of bark on average per visitation to a tree. These removed barks constitute a larger percentage of total bark from the tree. Therefore, it is likely that these smaller trees might be killed if the removed bark makes a greater than half of the total circumference.

Another finding in this study is the highly significant variation of the frequency of damage among the sampling plots in both areas. Spatial variation of damage reflects the selection of the feeding places by the elephants. Elephants caused less damage to the plots where the different tree species occurred in more equal proportions than the plots where one species was dominant. Elephants had a combination of positive, neutral and negative effects in woody plant species in Babile Elephant Sanctuary. The effect of elephants in the Sanctuary to change the physiognomy of riverine and woodland habitats in particular, was by reducing the number of woody species, and by changing plant species composition.

As a result of woody plant species breakage, there may also be an increase in shrub density. These resulted changes in shrub species composition and reduction in density. Regeneration of species may be decreased or arrested by elephants and other browsers.

The effect of vegetation change on other animal species has not been studied but there was evidence that gross vegetation change will result in declines in numbers of most other browsers. Changes to woodland physiognomy also affect the herbaceous layer, but these changes and the effect of vegetation change on grazing animals have not been investigated.

Results of this study have also demonstrated the value and extent of use of trees and shrubs by the local people. Many plant species are critical for the local people in the Sanctuary. The people depend on these resources for primary medical care, for provision of energy for cooking and heating in the form of wood fuel, and for fencing and construction of their homes. However, only a few plant species such as *Balanites glabra, Acacia mellifera, A. tortilis* and *A. seyal* seem to be widely used and important. These resources are still widely available, but ecological (frequent and prolonged drought conditions) and human-related factors (charcoal production, clearance for agriculture and unsustainable utilization) are potential threats to their future availability.

8.2. Recommendations

There is a need for more and longer-term studies in the region to understand exactly what impact the elephants have on the system. Satisfactory management of the elephant problem in BES will require detailed knowledge of the trends affecting damage and by elephants. Further monitoring should be undertaken to assess further changes and to develop a precise monitoring protocol.

Future research should also focus on detailed assessment of current vegetation status in the Sanctuary leading to a synthesis of current vegetation data (landscape/ land type) and to produce an estimate of areas that are potentially vulnerable to elephant impacts and set up monitoring programmes accordingly.

It is essential to conduct a comprehensive field-based quantitative assessment on actual use and availability of these tree and shrub resources. To avert the decline and lessened availability of these resources in the future, field-based monitoring as well as managed use by the local community is recommended. In particular, the understanding the relationships between the use of vegetation resources and the impacts of this use, and developing and implementing appropriate land-use policy based on this information, will require a fundamentally cross – disciplinary or hybrid approach: one which accepts the challenge to integrate anthropology, ecology and political analysis to represent dynamic interactions between people, environment and policy.

Rehabilitation by plantation especially the indigenous multi-purpose tree species that are highly threatened but still available in the valley should be given emphasis. This can be done by organizing the local communities. Sociological study also should be conducted to investigate the source of conflict between agriculturalists and pastoralists in the Sanctuary and this could provide base line information to develop proper management and conservation plan.

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10. APPENDICES

Appendix 1: List of identified woody plant species in BES (Or = Oromo language; S = Somali language), arranged alphabetically by genus (after Azene Bekele *et al.*, 1993).

Scientific name	Family	Vernacular name	Remark
Abutilon fruticosum	Malvaceae	Balanbal (S)	shrub
*Acacia albida**	Fabaceae	Garbi (Or)	tree
Acacia brevispica	Fabaceae	Hamareesaa (Or)	shrub
*Acacia bussei**	Fabaceae	Halloo (Or)	tree
Acacia etabaica	Fabaceae	Dodoti (Or)	tree
*Acacia mellifera**	Fabaceae	Bilaila (Or)	shrub
*Acacia nilotica**	Fabaceae	Serkema (Or)	shrub
Acacia oerfota	Fabaceae	Ajoo (Or)	shrub
*Acacia robusta**	Fabaceae	Wangeyo (Or)	tree
*Acacia senegal**	Fabaceae	Sobensa (Or)	shrub
*Acacia seyal**	Fabaceae	Wachu (Or)	shrub
*Acacia tortilis**	Fabaceae	Dhadhacha (Or)	tree
Acokanthera schimperi	Apocynaceae		shrub
Allophylus rubifolius	Sapindaceae		shrub
Asparagus leptocladodius	Asparagaceae	Keleme sere (Or)	shrub

Balanites aegyptica	Balanitaceae	Baddanno (Or)	tree
*Balanites glabra**	Balanitaceae	Kutka (S)	tree
Bascia minimifolia	Capparidaceae	Meygag (Or)	tree
*Berchemia discolor**	Rhamnaceae	Jajaba (Or)	tree
Cadaba farinose	Capparidaceae	Kelkelcha (Or)	shrub
*Canthium setiflorum**	Rubiaceae		shrub
Capparis sepiaria	Capparidaceae	Riga gange (Or)	shrub
*Capparis tomentosa**	Capparidaceae	Gemora (Or)	shrub
Carissa spinerum	Apocynaceae	Agemsa (Or)	shrub
Combretum molle	Combretaceae	Obelbiyodka (S)	tree
*Commiphora erythrae**	Burseraceae	Kedhon (S)	tree
Commiphora schimperi	Burseraceae		tree
Cordia monoica	Boraginaceae	Medhero (Or)	shrub
Crotalaria laburnifolia	Fabaceae		shrub
Dichrostachys cinerea	Fabaceae	Jirme (Or)	shrub
Dodonoea angustifolia	Sapindaceae	Dhidicha (Or)	shrub
Euclea schimperi	Ebenaceae	Mieysa (Or)	shrub
Flueggea virosa	Euphorbiaceae	Kechachile (Or)	Shrub
*Grewia bicolor**	Tiliaceae	Sutanekebu (Or)	shrub
Grewia erythrea	Tiliaceae		Shrub
*Grewia flavescens**	Tiliaceae	Ogemdi (Or)	shrub
Grewia kakothamos	Tiliaceae	Midhayoo (S)	shrub
Grewia villosa	Tiliaceae		Shrub
Jasminum floribundum	Oleaceae	Biluu (Or)	shrub
Justcia schimperiana	Acanthaceae	Dhumuga (Or)	shrub

Kleinia squarrosa	Acanthaceae		shrub
Lanthana camara	Verbenaceae	Beke arkete (Or)	shrub
Melhania velutina	Stercullariaceae		shrub
Oncoba spinosa	Flacourtiaceae	Jilbo (Or)	tree
*Opuntia ficus-indica**	Cactaceae		tree
Prosopis juliflora	Fabaceae	Ged-adab (Or)	shrub
Rhus natalensis	Anacardiaceae	Dobobeeysaa (Or)	shrub
*Salvadora persica**	Salvadoraceae	Ade (S)	tree
*Senna obusifolia**	Fabaceae		shrub
Steganotaenia araliacea	Apiaceae		tree
*Sterculia africana**	Sterculiaceae	Geri (Or)	tree
*Tamarindus indica**	Fabaceae	Roka (Or)	tree
*Terminalia brownie**	Combretaceae	Bireysaa (Or)	tree
Trachilia emetica	Meliaceae	Ununuu (Or)	tree
*Ziziphus spina-christi**	Rhamnaceae	Kurkura (S)	tree

Key: * Common trees and shrubs found in BES most commonly used by the local community.

Appendix 2: Plants impacted by elephants at BES, arranged alphabetically by genus (after Azene Bekele *et al.*, 1993).

Species	**Utilization**	**Habitat and distribution in BES**
Acacia albida	Browsed	Along woodlands
Acacia brevispica	Browsed	More abundant in granites and low lying

	Uprooted, snapped stem	
Acacia bussei	Severely damage	Mainly in the southern part of BES
	Preferred species	
Acacia etbaica[#]	Considerable damage	Eastern half of the BES along rivers and woodlands
	Debarked	
Acacia mellifera	Favored species	Along rivers and woodlands
	Browsed	
Acacia nilotica	Browsed	Throughout the BES on low lying
Acacia robusta	Leaves browsed	Throughout BES on banks of rivers and streams
	Debarked	
Acacia senegal	Browsed	Throughout the BES
	Debarked	
Acacia seyal	Browsed	Throughout BES abound on basaltic soils
	Frequently uprooted	
	Ring barked	
	Leaves and pods	
Acacia tortilis	Browsed	
	Debarked	Throughout the BES
Acokanthera schimperi[#]	Trampled	Abundant along the sediments
Balanites aegyptiaca	Well browsed	Widespread in the BES
Balanites glabra	Browsed	Throughout BES on sandy and granitic soils
Berchemia discolor[#]	Fruits and leaves browsed	Throughout BES but rare, limited to granite, and sandy soils
	Branches broken	
Cadaba farinosa	Browsed	Throughout the BES
	Branches broken	

Carissa spinerum[#]	Browsed	Throughout the BES
	Branches broken	
Combretum molle	Well browsed	Along woodlands
Dichrostachys cinerea	Heavily browsed	Throughout the BES
	Branches broken	
	Browsed	
Dodonaea angustifolia	Heavily browsed	On the granitic and sandy soils
Euclea schimperi[#]	Debarked	Throughout the BES, often on flats
	Browsed	
Flueggea virosa[#]	Browsed	
		Widespread in the BES
Grewia bicolor	Browsed	Mainly in slopes
Grewia ferruginea	Severely browsed	Throughout in the BES
Kleinia squarrosa[#]	Pushed over	Mainly in the mountains
	Browsed	
Oncoba spinosa[#]	Browsed	Limited to the northern sides
	Branches broken	
Opuntia ficus-indica	Browsed	Throughout BES
Opuntia stricta	Browsed except in inaccessible areas	Mainly in slopes
Terminalia brownii	Browsed	Throughout BES

Key: # = observation by BES' scouts; all other observation by the author.

Appendix 3: Current situation of BES.

The Babile Elephant Sanctuary (where this study was based) is home to the only surviving elephant population in the farthest east of Horn of Africa. Recognizing the ecologically uniqueness of such a relic population in Ethiopia, a project was carried out in the sanctuary to investigate data on population dynamics, home ranges, the major conflicts occurring between people and elephants, and the efficacy of the law enforcement and extent of illegal use of wildlife.

However, a recent move by the investment commission of Ethiopia to give 10,000 hectares of the north western part of the land to a private company engaged in the cultivation of castor used for production of fuel is being described as a calamity to the already declining elephant population and other wildlife. The company, Flora Eco Power, headquarters in Germany that now possess the said land is involved in a land clearing using bulldozers in area that was earmarked for the elephants.

My intention here is to stress the possible catastrophe that might be caused following the Bio-diesel Project encroaching on Elephant Sanctuary; it is the contest for land between preservation and a delicate development. Once this habitat is gone, the last remaining elephants of the eastern African Horn will be extirpated.

Efforts are underway on the national and international levels to reduce the effect of crop-growing production in an area designated for conservation of elephants and indeed the entire ecosystem.

It is hoped that such efforts are productive and that an understanding will be reached between the local authorities and the Flora Eco Power Company to mitigate the stress on the ecosystem "(Yirmed Demeke, personal communication, 2007)".

11. DECLARATION

This thesis is my original work, has not been presented for a degree in any university and all sources of materials used for the thesis has been gratefully acknowledged.

Zelalem Wodu

Signature

Date