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The Spatial Distribution of *Balanites aegypti aca* (L.) Del. in Relation to Edaphic Factors, in Western Serengeti, Tanzania

By
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DEDICATION

To the memory of my loving mother, Raheli Musovu. Her love was beyond compare.

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ABSTRACT

The objective of this study was to explore the spatial distribution of *Balanites aegyptiaca* in relation to edaphic factors in Western Serengeti, Tanzania. Vegetation and soil samples were collected from 60 plots established in three sites A, B and C, which exhibit different conditions. In site A, *B. aegyptiaca* grows as the only woody species while in site B, it coexists with other woody species and in site C, the species does not grow at all. Soil samples were analyzed for macronutrients composition, electrical conductivity, organic matter, texture, bulk density and moisture content. Single factor Analysis of Variance (ANOVA) was used to test whether there was a significant difference in levels of measured soil parameters between the sites. Student t-test was used to test the difference in *B. aegyptiaca* populations between the sites. The test was also used to determine a significant difference in diversity indices of grasses and herbaceous species that grow under the canopy and that grow outside the canopy of *B. aegyptiaca*. ANOVA showed that sodium, potassium, clay, bulk density, organic matter and electrical conductivity levels were significantly higher in the sites where a pure stand of *B. aegyptiaca* is found ($P < 0.05$). Although *B. aegyptiaca* trees with significantly high dbh and crown diameter values were recorded in the sites where a pure stand of the species is found ($P < 0.5$), their heights were not significantly different from those recorded at the site where the species coexists with other woody species B ($P > 0.05$). The t test revealed a significant high diversity index of the grasses and herbaceous species under the canopy of *B. aegyptiaca* than outside the canopy. This study concluded that, *B. aegyptiaca* dominates massive water logged and compact soils of western Serengeti, because of its tolerance to saline and sodic soils. It also concluded that the population of the species is facing danger of decreasing.

Key words: *B. aegyptiaca*, soil, distribution, population structure, western Serengeti

1 INTRODUCTION

1.1 General introduction

Drylands are areas characterized by high temperatures, low rainfall (less than 800mm of rainfall per annum) and high evapotranspiration (Dejene *et al.*, 1997). It is estimated that these ecosystems cover one third of the earth total land surface and about half of this area is in economically productive use as range- or agricultural land (CCD Secretariat, 1997). Sixty percent of the drylands is already degraded resulting in an estimated annual economic loss of USD 42 billion worldwide (CCD Secretariat, 1997).

In Africa, the drylands cover about 65% of the total land of south Sahara and are susceptible to various agencies of land degradation (Dejene *et al.*, 1997). Despite their water stress, the drylands support a considerable high variety of both flora and fauna although the status of wild plant and animal species diversity is poorly documented (CCD Secretariat, 1997). The dryland species and ecosystems have developed unique strategies to cope with low and sporadic rainfall. They are highly resilient and recover quickly from prevailing disturbances such as fires, herbivore pressure and drought. These attributes have great significance for the global system, especially in the context of climate change. One of the most adapted keystone plant species in the drylands is *Balanites aegyptiaca,* which is commonly known as desert date. *B. aegyptiaca* is known as bedeno, jemo and kudkuda in Amharic (Bein *et al.*, 1996) while in Kiswahili it is known as mwambangoma (Mbuya *et al.*, 1994).

1.2 Taxonomic features of *B. aegyptiaca*

Balanites aegyptiaca is a flowering plant species that belongs to the family *Balanitaceae. Balanites*, the only genus in the family, has been variously assigned to several families, notably *Zyophyllactes* and *Simaroubalaceae*. However, the alternate, bifoliolate, stipulate leaves associated with spines, which are often supra axilliary are together distinct and with other characters such as free loculi and the nature of fruits, uphold that the genus should stand as monogeneric family (Sands, 1989).

The genus *Balanites* contains nine species and it reaches its greatest diversity in Africa where seven species are known to occur. Two species occur in India and Burma. *B. glabra* occurs in northern Somalia, Kenya and northern Tanzania, while *B. ratundifolia* is restricted in the Eastern province of Kenya. *B. belicellaria* is distributed in Eastern Africa from Uganda to Swaziland and Natal. *B. aegyptiaca* with its four varieties is well distributed all over Africa arid and semi arid regions to sub-humid Savannah (Mbuya *et al.*, 1994 and Sands, 1989). According to Sands (1989) and Bein *et al.*, (1996) *B. aegyptiaca* is well distributed in dry and Acacia woodlands from Senegal to Somalia and from Egypt to Zimbabwe. *B. aegyptiaca* requires 200-800mm rainfall, and it thrives well at 0-2000 metres above sea level (Mbuya *et al.*, 1994 and Bein *et al.*, 1996).

B. aegyptiaca is a multibranched, spiny shrub or tree that grows up to more than 10 m high (Sands, 1996). Crown is round and dense with long stout branchlets. Trunk and bark are grey and deeply fissured longitudinally. The leaves are compound and spirally arranged on the shoots, dark green with two firm coriaceous leaflets. The flower buds are oval and tomentose. Individual flowers are hermaphroditic, pentamerous and actinomorphic. These flowers have diameters that

range from 8-14 cm and are generally greenish. The fruits are green and ellipsoid up to 4 cm long. Ripe fruits are brown or pale brown with a brittle coat enclosing a brown-grey pulp and a hard stone seed (Bein *et al.*, 1996).

1.3 Economic importance of *B. aegyptiaca*

B. aegyptiaca is one of very important species in the dryland, which produces fruits even in very dry years (Bein e*t al.*, 1996). The economic value of *B. aegyptiaca* has been known in Egypt since ancient times (Yuonis, 1997). According to Mbuya *et al.*, (1994) and Bein *et al.*, (1996), *B. aegyptiaca* is known to have both direct and indirect values. Indirect values include what *B. aegyptiaca* contributes to the wider environment. For example, it provides shade, mulch, and acts as windbreaker and therefore can be used in agroforestry systems. Most of the direct values are the tangible output or the products, derived from the plant. In West Africa, for example, the fruits have been articles of commerce in the food market for a long period (Watt and Breyer-Brandwijk, 1962) probably due to the fact that, the flesh pulps of both unripe and ripe fruit is edible and can be eaten while dry or fresh (Bein *et al.*, 1996). The wood is good for firewood and produce high quality charcoal. In Egypt, the most important use in the past was the extraction of oil from the kernel. In addition, the fruit pulp was eaten raw or made into cakes and used for the preparation of an alcoholic drink (Younis, 1997). New shoots, which grow during the dry season, are used as animal forage. In Sudan, shoots are raw materials for manufacture of cakes that fatten sheep (El-Khidir *et al.*, 1983). Moreover, in Ethiopia during periods of food shortage people cut the newly growing succulent shoots and leaves and cook them like cabbage (Getahun, 1974).

Ethnobotanical studies have revealed medicinal values of *B. aegyptiaca.* Different parts of the tree, which include the fruit, kernel oil, leaves, resin, root, bark, shoots and seeds, are used to

treat a wide range of illnesses. The medicinal property is probably attributed to the presence of *saponin* (Watt and Breyer-Brandwijk, 1962). In Egypt, for example, leaves have been used in the past as herbs (Younis, 1997).

An emulsion made from the fruit or bark is lethal to fresh water snails that are the host of miracidal and cercaria stages of bilharzias, water fleas that acts as a host to the guinea worm, tadpole, molluscs and fishes. The emulsion is still being used as anthelmintic in different parts of the world and remedy for syphilis (Watt and Breyer-Brandwijk, 1962). Decoction of roots is used to treat malaria. Roots boiled in soup are used against oedema and stomach pains. Roots are also used as an emetic while bark infusion is used to treat heartburn in many parts of Africa (Watt and Breyer-Brandwijk, 1962).

In the past, the bark was used in Libya and Eritrea as a soap substitute, while in Sudan and Far East; the leaves were used as a detergent to clean malignant wounds and silk (Watt and Breyer-Brandwijk, 1962).

1.4 Justification of the study

Despite its importance, *B. aegyptiaca* faces considerable threats worldwide and available evidence suggests that its population is declining (BIC, 2002). In Asia and Egypt, it is already considered as a rare species (Younis, 1997).

Serengeti ecosystem is outstanding in terms of biological diversity, aesthetic and economic values (McNaughton and Banyikwa, 1995). It is significant for its contribution in the gross domestic product (GDP) of Tanzania through tourism (MNRT, 1991). It harbors some 1.7

millions wildebeest, 250,000 zebras and a vast number of ungulates and carnivores. The ecosystem is also known to support the largest herds of migratory ungulates, and probably the highest concentration of large predators in the world (Maddock, 1979 and Sinclair, 1995).

Noy-Meir (1992) observed that the stability, dynamics and resilience of savanna ecosystem are significantly affected by browsing. *B. aegyptiaca* being one of the most important browse species could be affected. A study done by Claudius and Charles, (1999) in Tarangire National Park, revealed a significant decrease in population of wood species including *B. aegyptiaca* because of increased number of elephants.

Human population growth rate on the western frontiers of Serengeti ecosystem was 4% in 1990s and is increasing every year (Packer, 1996). Therefore, although Serengeti ecosystem is known for its high biological diversity and conservation status, there has been noticeable pressure from human population increase that could be extended to *B. aegyptiaca.* The reduction of the species as a result of human induced destruction of continuous habitat creates problems and challenges to ecologists, conservationists and resources managers (Noble, 1995). In western Serengeti, the influence of increased human population on vegetation cannot be underestimated.

In Egypt, *B. aegyptiaca* is now considered as the vulnerable species because it is rare and its population has declined (Younis, 1997). According to Younis (1997), the cause of its vulnerability is the alteration of all Nile valley to the agricultural lands which later caused the loss of most favorable habitat, while in the surrounding desert, the tree was overused for grazing, fuel-wood and timber (Younis, 1997).

Since the ecological studies have a significant contribution to biodiversity conservation (Noble, 1995), it is intended to present basic ecological information of *B. aegyptiaca*, through this study, which will probably help in conservation of this keystone plant species in the drylands. The study also intended to provide additional information on the plant diversity of the western Serengeti ecosystem.

1.5 Objectives and research questions

1.5.1 General objective

To explore the spatial distribution of *B. aegyptiaca* in Western Serengeti ecosystem and its relation to edaphic factors.

1.5.2 Specific objectives

The following were specific objectives of this study:

(i) To determine the population structure of *B. aegyptiaca* in Western Serengeti

(ii) To explore the spatial distribution of *B. aegyptiaca* and its relationship to the edaphic factors.

(iii) To assess the influence of *B. aegyptiaca* on the undercanopy herbaceous and grass species.

1.5.3 Research questions

The present study aimed at answering the following questions

(i) How is the current population of *B. aegyptiaca* in western Serengeti distributed?

(ii) Do edaphic factors influence the spatial distribution of *B. aegyptiaca* in western Serengeti?

(iii) Does *B. aegyptiaca* attract herbaceous and grass species?

2 LITERATURE REVIEW

2.1 Distribution pattern

Distribution evidence allows the appreciation of the environmental change over a wide geographical scale (Mueller-Dombois and Ellenberg, 1974). An aspect of distribution which is most stressed is the difference between places which have relatively little change over long periods. Some areas are rich in the number of species and endemics while areas subject to severe disturbances are impoverished due to both natural and human influences.

The importance of succession on species diversity is based on the fact that species that successfully invade a biotope dominate the scene for a period and form a closed community. However, living things modify their own habitat so as to cause one community to give way to another in a variety of ways. For instance, as the trees increase in size, they provide more shade, higher humidity and different conditions of food and cover. New types of animals and plants species can find suitable living conditions under this modified habitat conditions and hence species diversity increases. According to Asferachew *et al.*, (1998), *B. aegyptiaca* tree provides a good microclimate that favor growth of herbaceous and grass species under its canopy. However, some plants can perform very well in one country but poorly in another country with different climate. The present study therefore involved determination of the influence of *B. aegyptiaca* tree on herbaceous and grass species under its canopy, since very little is known about the influence of *B. aegyptiaca* on the herbaceous and grass species in Western Serengeti.

2.2 The influence of edaphic factors on the distribution of tree species

In all ecological zones, plant species are affected by both abiotic and biotic factors. Biotic factors include association and competition with other herbivores, other plants and microorganisms as well as human interference. Abiotic factors include climate, topography, altitude, edaphic factors and light intensity. These abiotic factors interrelate among themselves. For example, geographic factors such as altitude and gradient have an influence on vegetation and in combination, they all influence edaphic factors. Edaphic factors include, soil structure, soil moisture, texture, pH, exchangeable bases, cation exchange capacity and fertility as a whole (Holmes, 1995). Soil fertility as a whole refers to both physical and chemical fertility. Capacity of the soil to provide plants with foothold, moisture and air is regarded as physical fertility. On the other hand the ability of the soil to provide plants with essential elements in a proper concentration is regarded as chemical fertility of the soil (Holmes, 1995).

Other important factors that affect plant life are light and available space in the site. Several studies in South America and Africa (Basnet, 1993; Olivera-Filho *et al.,* 1994 and Lovett, 1996) have revealed a significant influence of topography and edaphic factors as one of the most important abiotic factors causing spatial distribution of trees in the tropics. The studies also revealed high correlation coefficients between topography and edaphic factors.

The physical and chemical properties of soils are a product of continual interactions between soil biota and abiotic factors (time, rainfall, topography and parent materials). Water, for example, casts a stronger influence on the biota since many are adapted to life in a saturated atmosphere (Coheman and Crossley, 1996). The soil formation process, which is the result of the interaction of climate, organisms, parent material and topography, produces various soil types with unique

profile development. Soil texture and the capacity for nutrient supply and retention are both important to primary producers in the soil and are affected by mineral and organic matter content (Coheman and Crossley, 1996).

Although there have been several studies on the influence of edaphic factors on the distribution of vegetations in western Serengeti, the autecological study on *B. aegyptiaca* is missing. The information on the influence of edaphic factors on the spatial distribution of *B. aegyptiaca* is unclear prior to the undertaking of the present study. In the present study the influence of edaphic factors on the distribution of *B. aegyptiaca* is examined, with the following variables considered when carrying out the study.

2.2.1 Bulk density

Bulk density is the ratio of the mass of dry soil to the volume of soil (Blake and Hartge, 1986). It is a widely used value because it is directly related to soil porosity, water content and structural condition of the soil, particularly compaction. Recent study on soil bulk density has revealed that, root penetration is totally hindered when the bulk density exceeds 1.8g/cm^3 (Arshad *et al.*, 1996). Different plant species have different tolerance to the soil compaction, which is attributed to bulk density. This study intended to reveal the degree of tolerance of *B. aegyptiaca* trees to soil compaction.

2.2.2 Soil texture

The soil particles are derived from two major sources. These are the crystalline minerals weathered from primary rocks and those derived from decomposing animal and plant residue (Coheman and Crossley, 1996). The clay fraction, which is important in imparting specific

physical properties to the soil, and to microbial and plant nutrients via availability, is composed of particle size less than 2mμ. Unlike the larger sand silt particles, clays are recrystalised from the weathering products of primary minerals and are extensively high in surface area per gram (Coheman and Crossley, 1996). The larger area plays a big role in adsorbing and desorbing inorganic and organic constituents in the soil. Most of the behaviour and properties of soils are reflected by soil texture (Table 1).

Table 1. Generalized influence of soil separates on some behavior and properties of soils

Properties	**Sand**	**Silt**	**Clay**
Water holding capacity	Low	Medium to high	High
Drainage rate	High	Slow to medium	Very slow
Organic matter	Low	Medium to high	High to medium
Decomposition of organic matter	Moderate	Medium	Slow
Susceptibility wind erosion	Rapid	Medium	Slow
Susceptibility to water erosion	Low	High	Low if aggregated and high if not aggregated
Ability to store plant nutrient	Poor	Medium	Relatively high
Resistance	Low	Medium	Relatively high

Source: Brady and Weill (1999).

2.2.3 Water content

Water content plays a significance role in the soil plant system. It is involved in physical-chemical and biological activities in the soil. It affects processes such as weathering of rock, mineral, soil formation and soil erosion. Plant nutrient availability depends largely on soil water,

since it is a solvent for plant nutrients and a medium for uptake into plants. It is also essential in photosynthesis and other plant metabolic activities. Plants are commonly classified based on their tolerance to water stress (Donahue, 1995).

The main source of water in terrestrial ecosystem is precipitation and can be lost through percolation to ground water, stream flow, removal by plants, evaporation and surface run off. Water content is expressed either as the ratio of mass of water present in the sample to the soil mass after it has been dried to constant weight, or as the volume of water present to the total volume of the sample (Gardner, 1986).

2.2.4 Soil reaction, pH

The degree of salinity or acidity (pH, soil reaction) is the master variable that affects chemical, physical and biological properties of the soil (Brady and Weill, 1999). According to Brady and Weill (1999), no other single chemical soil chemical characteristic is more important in determining the chemical and physical environment of higher plants and soil microbes than the soil pH. Whether a soil is acidic, neutral or basic, it accounts for the solubility of various compounds, the relative binding of ions to exchange sites and the activities of the various microorganisms (McLean, 1982).

Climate influences acidity and alkalinity in the soils. In arid and semi arid regions such as Western Serengeti, soils tend to be quite basic because there is no sufficient rainfall to leach out most of the base-forming cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) (McLean, 1982).

Nutrient availability in the soil decrease when the pH is above 8.5 and such soils become very poor in fertility. At such high pH values, most of micronutrients form insoluble hydroxides that are not available to the plant. At slightly acidic soil (pH = 6 -7), most micronutrient cations are soluble enough to satisfy plant needs without becoming so soluble to the toxic level. Therefore, most elements are readily available within 6 - 7.5 pH ranges. In acidic soil (pH < 5) aluminum increases to toxic level. At pH values above 8 as recorded, for example, ammonium ion (NH_4+) is present mainly as ammonia gas (NH_3), which is lost from the soil, and it also inhibits the activity of (NO_2-) oxidizing bacteria (Brady and Well, 1999).

2.2.5 Soil organic matter

Soil organic matter has been defined as the organic fraction of soils including plant, animal and microbial residues fresh and at all stages of decomposition and the relatively resistant soil humus (Nelson and Sommers, 1982). However, for analytical purposes, soil organic matter includes only those organic materials that accompany soil particles in passing through a 2mm sieve. The soil organic matter influences many soil properties (Nelson and Sommers, 1982) including the capacity of soil to supply Nitrogen, Phosphorous, Sulphur and trace elements to plants. According to Stevenson (1985), organic matter content strongly affects soil fertility by increasing the availability of plant nutrients, improving soil structure and water-holding capacity, acting as an accumulation phase for toxic, heavy metals in the soil environment. It also influences the degree of aggregation of soil and overall structure, which affects water relationship, such as infiltration, retention and aeration of the soil. Soil color changes with organic matter content in turn affect temperature relationship.

2.2.6 Soil exchangeable bases

Sodium, potassium, calcium and magnesium are among the important exchangeable bases in the soil. These bases activate about 80 different enzymes responsible for plant and animal processes. They are components of plant cytoplasmic solution controlling osmotic potentials thereby reducing water loss from the plant cells and increasing the ability of roots to take up water from the soil. According to Brady and Weill (1999) potassium helps the plant to adapt to environmental stresses.

Although exchangeable bases play very crucial role in plant life, they become toxic at higher concentrations. Different plant species respond to different salt affected soils in different ways. High soluble salt concentration through their effect on osmotic potentials reduces plant growth on saline soils. Root cells as they come in contact with a soil that is high in salt will loose water by osmosis. There are other influences of saline and sodic soils on plant life. According to Brady and Weill (1999) bicarbonate, other ions and active sodium have adverse effect on plant metabolism. Also, in such soils there is oxygen deficiency due to break down of soil structure.

2.2.7 Soil nutrients

There are about 17 important soil nutrients needed by plants of which 7 are needed in large amounts, ie they are macronutrients. However, for the purpose of the present study only phosphorous and nitrogen were considered as they play a more critical role than other elements in the physiology of plants. The Nitrogen, and Phosphorous are macronutrients in the soil and their main source in the soil is organic matter (Wild, 1993 and Brady, 1994).

Nitrogen is an integral component of many essential plant components such as nucleic acids, chlorophyll, and protein. It is a major part of all amino acids, which are the building blocks of all proteins including enzymes, which control virtually all biological processes. It is primarily found in the organic form in the soil and taken up by plants in anionic form such as nitrate (NO_3^-), and in cationic form as ammonium (NH_4^+) ions.

Phosphorous on the other hand, enhances many aspects of plant physiology including fundamental processes of photosynthesis, nitrogen fixation, flowering, fruiting (including seed production) root growth and development (Brady and Weils, 1999). It is also an essential component of deoxyribonucleic acids (DNA), which carries genetic characteristics of organisms, and ribonucleic acids, which is essential for protein synthesis and cell division (Brady and Weill, 1999).

3 MATERIALS AND METHODS

3.1 Study Area

3.1.1 Location

The study was conducted in western Serengeti (Figure 1). Serengeti ecosystem is located west of the Great East African Rift Valley, between $34^0 00'$-$35^0 15'$ E and $1^0 30'$- $3^0 20'$ S. The Serengeti ecosystem is about 130 kilometers north west of Arusha.

3.1.2 Climate

The climate of the study area is as summarized in a climatic diagram (figure 1) adopted from Walter (1985). Serengeti ecosystem exhibits bimodal rainfall patterns ranging from 400 mm to 1100 mm per annum with peaks in December and April (Sinclair, 1995). Rainfalls tend to decrease towards the east and increase toward the north and west (MNRT, 1991). The mean annual temperature is 20.8^0C, but the mean monthly temperature varies between 26^0C in the hot months of October-March and 13^0C during the colder months of May to August (Sinclair, 1995). The temperature variation is highly influenced by the Ngorongoro Crater highlands, which creates a rain shadow and the hydrologic cycle of Lake Victoria.

3.1.3 Physical features and soil

Serengeti ecosystem is part of the high interior plateau of East Africa. The highest peak is on the Eastern plains near the Gol Mountain and slopes from 1850m to 920m along Lake Victoria. In the north and along the western corridor are mountain ranges of volcanic origin. The two perennial Rivers Duma and Mara (Figure 1) that flow to the west pass through numerous marshes and waterholes (Wit, 1977).

The plains of Serengeti are mainly crystalline rocks overlain by volcanic ash with numerous granitic rock outcrops (kopjes). Soils on the eastern plain are highly saline, alkaline and shallow as a result of their recent volcanic origin. These soils become progressively shallow and more alkaline on the southeastern plains (Wit, 1977 and Sinclair, 1995).

3.1.4 Vegetation

Grasslands are the major vegetation type on the undulating open plains (Wit, 1977). Dominant species are couch grass, *Digitaria macroblephara, Sporobolus stapfianus* and *Themeda triandra* (McNaughton and Banyikwa, 1995). In wetter areas, sedges such as *Kyllinga spp.* take over. There is an extensive block of *Acacia* woodland savanna in the centre, a more hilly and densely wooded zone covering most of the northern arm of the park, and some galley forest. The Lowlands comprise species of *Commiphora* and *Acacia drepanolobium* and *A. gerradii* while the upland woodlands comprise species of *Acacia lahai* and *A. seyal* var. Seyal (Schmid, 1975 and McNaughton and Banyikwa, 1995).

Seronera 1450m asl
[18]

25^0 C
560mm

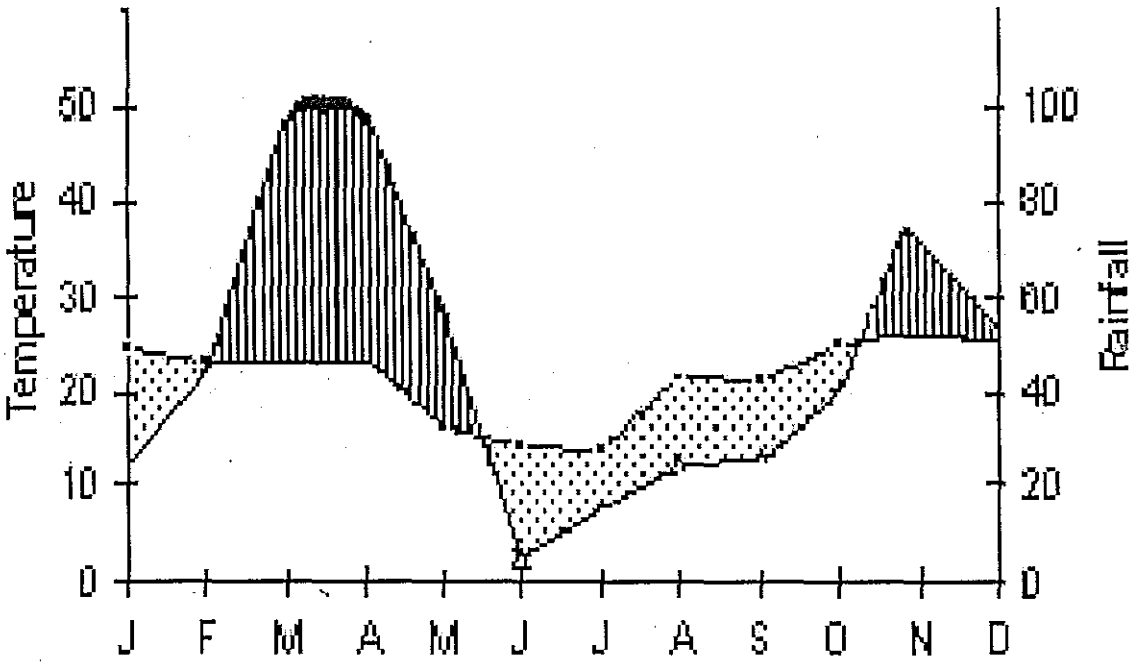

Fig 1: Climatic diagram showing mean annual temperature and mean annual rainfall for the last 18 years (1985-2003) of western Serengeti.

Source: Data obtained from Tanzania Meteorological Agency compiled for the station at Seronera metrological station

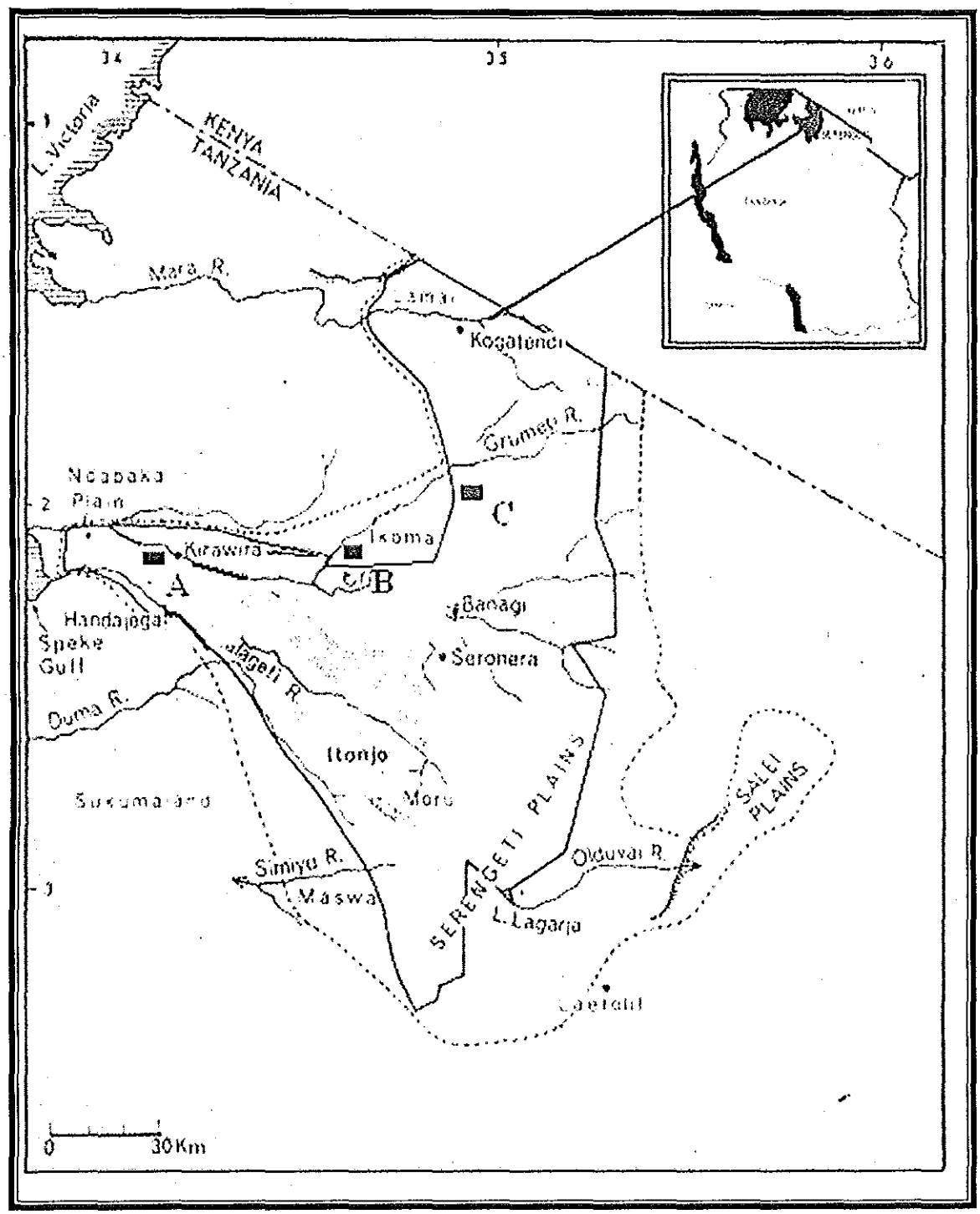

Figure 2: The Serengeti ecosystem (dotted line), Serengeti National Park (solid line). Study sites (cubes). A for site A, B for site B and C for site C

3.2 Reconnaissance survey

Reconnaissance survey was done in August 2003 to familiarize with the study site. During this period, the study area was stratified into three sites based on distribution of *B. aegyptiaca* (Goldsmith *et al.*, 1976). The sites included site A, a pure stand of *B. aegyptiaca*, site B, where *B. aegyptiaca* coexisted with other woody species and site C, where *B. aegyptiaca* does not grow at all (Figure 2).

3.3 Vegetation sampling

Vegetation data collection was done from 21st September to 20 October 2003. In each site, twenty plots of 25 m x 20 m were established along a 1.5 kilometers transect that ran from West to East. These plots were established at an interval of 50 metres. In each plot, height, diameter at breast height (dbh) and crown diameter of individual trees and saplings were measured and recorded. Plants whose diameter was < 1 cm were regarded as seedlings. These were defined as newly established plants that have not yet been damaged and thus have never resprouted. Saplings were determined as individuals whose diameter was $1 \leq 10$ cm. Plants with dbh greater or equal to 10 cm were regarded as trees (Luoga *et al.*, 2002). In the field, the circumferences of the plants were measured by using tape measure and calculations of dbh followed after the fieldwork. Associated species were identified and recorded in each plot. Identification was done in the field when possible, and those, which could not be identified, were, pressed and carried to the herbarium at University of Dar es Salaam, Botany department for identification.

The herbaceous and grass species that grew under the canopy of the *B. aegyptiaca* were listed and their cover - abundance estimated following a 1-9 Braun-Blanqet cover - abundance scales as

modified by Van der Maarel (1979) from 1 x 1 m quadrats randomly established under the canopy of the study tree. A herbaceous or grass species that occupied more than 75% of the plot was given a scale of 9, those occupied 50-75%, 25-50%, 12.5-25%, 12.5-25%, 5-12.5% and less than 5% of the plot, were given a scale of 8, 7, 6, 5, 4 and 3 respectively. Species that were represented by only few individuals in a plot were given a scale of 2 and the rare species a scale of 1. The same scales were used to record cover-abundances of the herbaceous and grass species outside the canopy of *B. aegyptiaca* from 1 x 1 m quadrats randomly established at about 3 m away from the edges of the trees canopies where influence of the tree canopy was considered negligible. This was done to assess the effect of study tree on herbaceous and grass abundance and composition.

3.4 Soil sampling and analysis

In each plot, four soil samples were taken from 0-20 cm depth at four angles of the plot by using a soil auger then a composite was made from them. 0 –20 cm depth was chosen so as to include to top and sub soils in the sample. A pit of 2-metre deep was dug in each site in order to describe the soil profile. In each pit, soil samples were collected at an interval of 10-cm to visualize the trend of soil parameter down the profile. Soil samples were kept in polythene bags, and properly sealed to avoid contamination and transported to the soil laboratory in the Botany Department, University of Dar Es Salaam for analysis.

Soil samples collected from the field were analyzed for physico-chemical parameters that include, bulky density, texture, pH, electrical conductivity (E.C), organic matter, total nitrogen, available phosphorous and exchangeable bases.

Total soil nitrogen was determined by using a semi-micro Kjeldahl digestion (Allen 1989) and colorimetric determination of the resultant ammonium by colour reaction (Endo-phenol blue method).

Soil Exchangeable Bases (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) were analyzed using Atomic Absorption Spectrophotometer (AAS) as described by Allen (1989) and readings were taken in meq/100g.

Electrical conductivity was determined electrochemically as described by Juo (1978) and the readings were taken in μS/cm.

3.5 Data analysis

Both descriptive and inferential statistics were used in the data analysis. The cover- abundance of the grass and herbaceous species were used to calculate Shannon-Wiener-Diversity Index (H′) as adopted from Magurran (1988). The Shannon-Weiner Diversity index (H′) was obtained from the following formula:

$H' = \sum pi \ln pi$

Where H′ = Shannon diversity index

pi = proportion of abundance of the i^{th} species expressed as a proportional of total cover.

ln = natural logarithm

Student t-test (Zar, 1999) was used to test whether there was significant difference in the *B. aegyptiaca* tree characteristics between the two sites where it was recorded. T-test was also used to test whether there was a significant difference in herbaceous and grass species diversity between the canopy of *B. aegyptiaca* tree and outside the canopy. Single factor analysis of

variance (ANOVA) was used to test whether there was a significant difference in soil parameters between the three sites (Zar, 1999). Also, Pearson correlation was performed to determine the correlation among the environmental variables.

4 RESULTS

4.1 Soil analyses

4.1. 1 Soil profile

The soils of site C were relatively deeper (more than two meters) than those of sites A and B. According to USDA (Soil survey staff, 1998) soil classification, the soils of site A are classified as Vertisol. On the other hand, the soils of site C are classified as Ultisols or Alfisol. The soil profile studies also revealed the presence of a restricting zone that extends from 40cm to 60cm depth along the soil profile of site A. In the other sites such zone was not found.

4.1.2 Bulky density

There was a decrease in bulk density from site A to site B and C (Table 2). It was observed that the bulky density decreased down the profile in all sites. The highest mean bulk density was recorded in site, A which was 1.673 ± 0.04325, followed by site B that was 1.381 ± 0.04324, and site C had the lowest mean bulk density, which was 0.768 ± 0.01015. Single factor Analysis of variance, showed that, soils collected from site A had significantly higher bulk density than those from site B. Also, soil samples from site B had significantly higher bulk density compared to that collected from site C ($F = 208.06$, $P = 0.001$).

4.1.3 Soil texture

In sites A and B, clay texture was dominant, while in site C, sand was dominant (Table 2). The highest percentage clay was recorded in site A (71.5 ± 1.688) followed by site B (65 ± 0.8028) while the lowest was recorded in site C (6.8 ± 0.388) (Table 2). Single factor Analysis of variance (ANOVA) showed that, soil samples collected from site A were significantly higher in percentage clay than those collected from site B and C ($F = 1044.5$, $P < 0.001$).

Percentage sand showed a different trend since, the highest percentage sand was recorded in site C (64.5 ± 6191) followed by site B (6 ± 0.6146) and the lowest was recorded in site A (3.4 ± 0.5617) (Table 2). Single factor analysis of variance confirmed that the soil samples collected from site A had significantly higher percentage in clay than those samples collected from site B and C ($F = 3326.1$, $P = 0.001$) (Table 2).

Soil samples collected from all sites showed no great variation in the percentage of silt fractions. Soil samples with highest percentage silt were collected from site C (24.9 ± 0.2769) followed by those collected from site B (24.7 ± 0.1528), while the soil collected from site A had the lowest percentage of silt (23.7 ± 0.1528) (Table 2). Single factor analysis of variance confirmed statistically that, no significant difference in percentage silt between soil samples collected from sites B and C ($F = 0.986$, $P > 0.05$) (Table 2). This was also the case between the soil collected from sites B and C ($p > 0.05$). However, the single factor analysis of variance confirmed that, soil sample collected from site C had significantly higher percentage silt than that collected from site A ($F = 5.918$, $p < 0.05$) (Table 2).

4.1.4 Exchangeable bases

The highest concentrations of potassium were recorded in site A (10.581±0.4221 meq/100g) followed by site B (13.547±0.715 meq/100g) while the lowest concentrations were recorded in site C (8.33±0.1098 meq/100g) (Table 2). The mean calcium concentrations in site A was 19.953 ± 0.2358 meq/100g, followed by 16.701 ± 0.4656 meq/100g in site B and 16.171 ± 0.1164 meq/100g in site C. Magnesium concentration was almost evenly distributed among the three sites. The highest concentration of magnesium was recorded in site A (3.487 ± 0.586 meq/100g) followed by site C (3.457 ± 0.1291 meg/100g) and site B had the lowest (3.357 ± 0.1549

meq/100g). Soil profile description showed a relatively increase in levels of bases down the profile.

Analysis of variance confirmed that as exchangeable bases, sodium, potassium significantly higher in site A than in site B and C (F = 351.78, P = 0.001; F = and F = 43.989, P = 0.001 respectively) (Table 2). The single factor Ana confirmed that, there is no significant difference (F = 0.5653, p > 0.05) in magn three sites.

4.1.5 Electrical conductivity (EC)

High electrical conductivity values were recorded from site A (2307 ± 749.49µ site B (608.7 ± 125.80µS/cm) while the lowest EC values were recorded in 14.707µS/cm) (Table 2). Analysis of variance showed that soil samples significantly higher EC value than that collected from site B and C (F = 73.253,

4.1.6 Soil nitrogen

The lowest value was recorded from site B (0.388 ± 0.1497 %) followed by 0.1522 %) and site A had the lowest value (0.34 ± 0.19%) (Table 2). An revealed no significant difference in total available nitrogen between the three P > 0.05).

4.1.7 Soil Phosphorous

Available soil phosphorous was high in the top soil (0-20cm) and decreased Higher available percentages of phosphorous were recorded in site A (0.

followed by site B (0.0355 ± 0.078%) and the lowest was recorded in site C (0.0276 ± 0.00452%) (Table 2). Analysis of variance showed that, soil samples collected from site A had significantly higher phosphorous content than those collected from site C ($F = 4.093$, $P < 0.05$). There was no statistically significance difference in available phosphorous between the soil samples collected from site A and B ($F = 2.772$, $p > 0.05$). This was the case also between the soil samples collected from site B and C ($F = 1.321$, $p > 0.05$).

4.1.8 Soil organic matter

The percentage organic matter was higher in the top soil (0-20cm depth) and decreased down the profile. Site A was found to have more percentage organic matter compared to site B and C (F. Analysis of variance revealed no significant difference in organic matter between the three sites ($F = 0.1717$, $p > 0.05$).

4.1.9 Soil pH

In all sites, pH increased down the soil profile. High pH values were recorded from soil samples collected from site A (9.29± 0.798) and B (7.87 ± 0.256), while lower pH values were recorded from samples collected from site C (6.29 ± 0.179) (Table 2). Analysis of variance showed that soil samples collected from site A had significantly higher pH values than those collected from site B and C ($F = 54.688$, $p = 0.001$).

4.1.10 Correlation among the edaphic variables

The present study showed high correlation among several environmental variables (Table 3). Electrical conductivity was positively correlated with sodium, potassium and calcium ($r = 0.87$, $r = 0.82$, $r = 0.52$ respectively) (Table 3). Organic matter was positively correlated with

phosphorous (r = 0.51). While clay positively correlated with most exchangeable bases (table 3) sand negatively correlated with pH, electrical conductivity, sodium, potassium, calcium and phosphorous (r = -0.76, -0.77, -0.95, -0.99, -0.28 and -0.69, respectively).

Table 3: Single factor an
***** Extremely significan**
Not significant (p value >

VARIABLE
PH
Site A
Site B
Site C
Electrical conductivity
Site A
Site B
Site C
Sodium
Site A
Site B
Site C
Potassium
Site A
Site B
Site C

Table 2 continues

Calcium	(n
Site A	19
Site B	16
Site C	16
Magnesium	(r
Site A	3.
Site B	3.
Site C	3.
Phosphorous	(%
Site A	0.
Site B	0.
Site C	0.
Nitrogen	(%
Site A	0.
Site B	0.
Site C	0.

Table 2 continues

Clay	%
Site A	7
Site B	6
Site C	6.
Silt	%
Site A	2
Site B	2
Site C	1
Sand	%
Site A	3.
Site B	6
Site C	6
Bulk density	g
Site A	1.
Site B	1.
Site C	0.
0rganic matter	%
Site A	1.
Site B	0.
Site C	0.

Table 3. Correlation

	pH	E.C
pH		
E.C.	0.91 ***	
Na	0.87 ***	0.92 ***
K	0.82 ***	0.85 ***
Ca	0.52**	0.71 **
Mg	-0.02 ns	0.10
N	-0.19 ns	-0.1
P	0.86 ***	0.97 ***
O.M	0.43 *	0.50 *
Sand	-0.76 **	-0.7 **
Silt	-0.49 *	-0.5 **
Clay	0.77 **	0.79 **
BK	0.87 ***	0.89 ***

Key: data in the table
*** **Extremely sig**
0.01) and ns Not sign

4.2 Vegetation analyses

4.2.1 Vegetation characteristic of the study area

A total of 155 plant species from 43 families were recorded in this study from three sites namely site A, B and C. In site A (Plate 1), *B. aegyptiaca* grows as only woody species while in site B (Plate 2) the species coexists with other woody species and site C it does not grow at all. The results showed that more plant species were recorded a site where *B. aegyptiaca* does not exist than the sites where the species exist (Appendix).

Result as presented in table 3 showed variation in trees species composition and cover-abundance between the three sites. The result showed that site C had more trees species than sites A and B.

In a pure stand of *B. aegyptiaca, Themeda triandra, Digitaria macroblephara* and *Sporobolus stapfianus* were found to have high cover-abundance values than other grass species while in site *B. aegyptiaca* coexist with other woody species, *Themeda triandra, Hyparrhenia filipendula* and *Pennisetum polystachion* had high cover abundances than other grasses. *Themeda triandra* and *Hyparrhenia filipendula* had high cover abundance values in the site where there was absence of *B. aegyptiaca.*

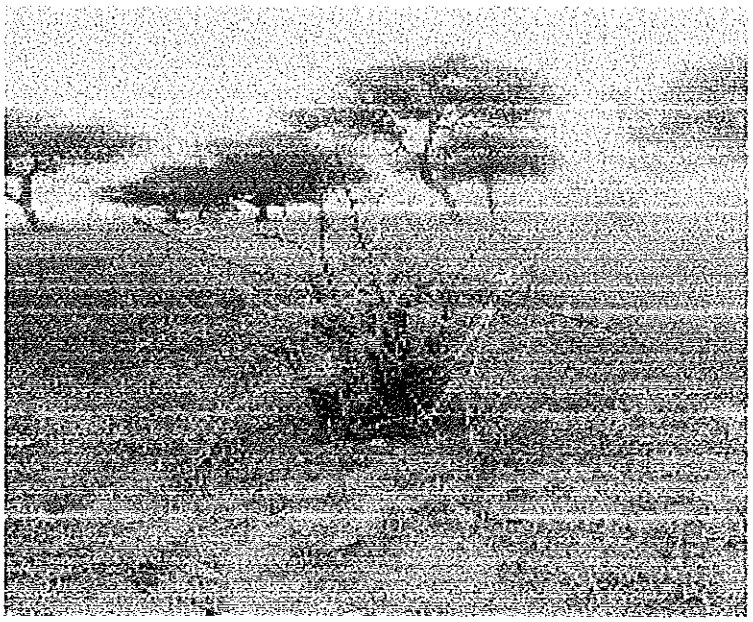

Plate 1. Site A. *Balanites aegyptiaca* grow as only woody species

Plate 2. Site B. *B. aegyptiaca* coexist with other woody species. A – *Acacia spp*, B – *B. aegyptiaca*

Table 4. The mean cover-abundances of tree species recorded in site A, B and C respectively

Tree species	Mean cover-abundance in site A ± SD	Mean cover-abundance in site B ± SD	Mean cover-abundance in site C ± SD
Acacia nilotica	0	4.3 ± 0.21	2.3 ± 0.21
Acacia polyacantha	0	1	0
Acacia robusta	0	5.2 ± 0.17	0
Acacia senegal	0	6.6 ± 0.19	2.7 ± 0.14
Acacia seyal var. fistula	0	3.2 ± 0.12	0
Acacia seyal var. seyal	0	0	4.3
Acacia tortilis	0	4.1 ± 0.31	0
Albizia amara	0	0	1.1 ±0.3
Balanites aegyptiaca	7.8 ± 0.43	7.4 ± 0.42	0
Commiphora africana	0	0	1.3 ± 0.24
Grewia falax	0	1.7 ± 0.22	1.2 ± 0.11
Lannea schimperii	0	1	0
Lannea stuhlmannii	0	0	1
Lonchocarps eriochalix	0	1.5 ± 0.1	0
Ozoroa insignis	0	0	6.1 ± 0.26
Parinari curatelifolia	0	0	5.7 ± 0.31
Rhus natalensis	0	1	2.2 ± 0.25
Sclerocarya birrea	0	0	1
Strychnos spinosa	0	0	1
Terminalia mollis	0	0	7.6 ± 0.41
Ximenia caffra	0	0	1

It was also found that, the list of herbaceous and grass species that grow under the canopy of *B. aegyptiaca* was relatively higher than that of outside the canopy. Statistically, it was confirmed that grass and herbaceous species that grow under the canopy of *B. aegyptiaca* had significantly high species diversity index than those that grew outside the canopy of *B. aegyptiaca* ($t = 5.15$, $p = 0.001$).

4.2.2 Population structure of *B. aegyptiaca*

The result of population structure of *B. aegyptiaca* is shown in figure 3. From the figure there was a relatively high *B. aegyptiaca* seedlings density in site A than in site B. The mean *B. aegyptiaca* seedling density in site A and B is 42 and 28 seedlings per ha respectively. There was no significant difference in sapling density between site A and B. The mean *B. aegyptiaca* sapling density in site A and B was 15 and 16 saplings per ha respectively. There was relatively high density of *B. aegyptiaca* trees in site A than in site B. The mean *B. aegyptiaca* tree density in site A and B was 31 and 28 trees per ha respectively.

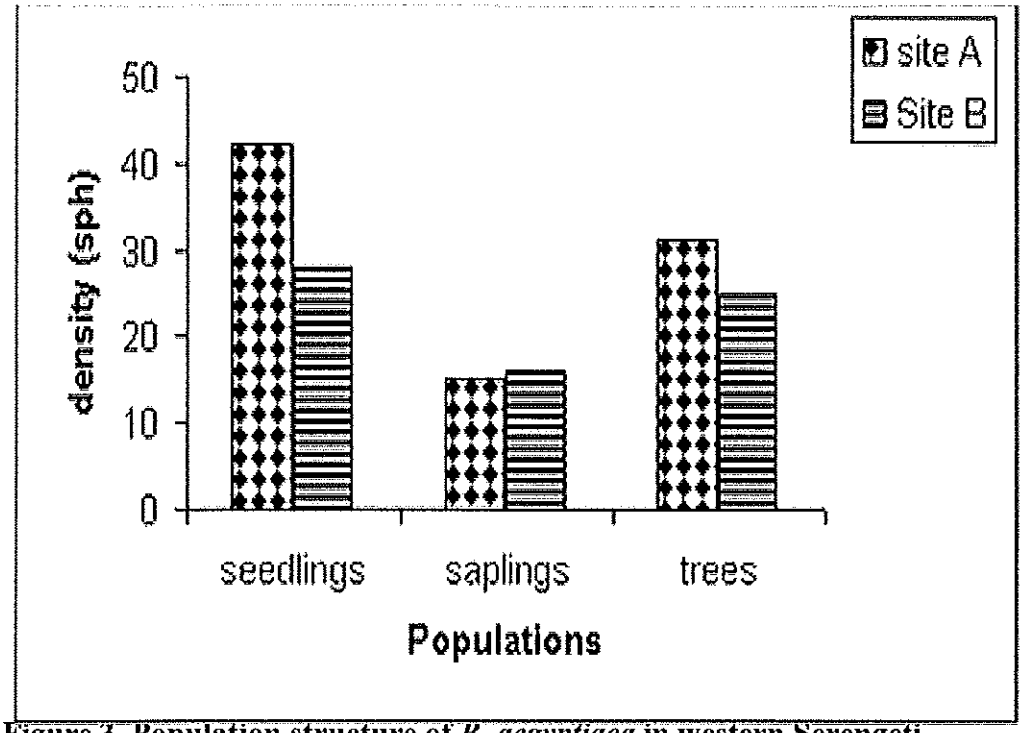

Figure 3. Population structure of *B. aegyptiaca* in western Serengeti

B. aegyptiaca trees with mean dbh 30.508±2.089 and 21.9±1.582 cm were recorded in site A and B respectively. Student t-test also confirmed that the *B. aegyptiaca* trees with significantly high

dbh were found in site A (t = 2.998, p = 0.001) (Table 5). DBH classification revealed that, more *B. aegyptiaca* trees were in 25 – 29.9 cm dbh class (Figure 4a).

B. aegyptiaca trees with mean height 8.13±0.2269 and 7.356 ±0.356 were found in site A and B respectively. It was statistically shown that there was no significant difference in heights of *B. aegyptiaca* trees recorded in site A and B (t = 1.27, p > 0.05) (Table 5). From height classification done, it was revealed that, more individual *B. aegyptiaca* trees were in 8-9.9 m height class (Figure 4b).

Trees with mean crown diameter 8.249 ±0.7725 m and 5.725 ±0.9011m were found in site A and B respectively. Student t – test confirmed statistically that site A had *B. aegyptiaca* trees with significantly high mean crown diameters than those in site B (T = 2.105, P =0.001) (Table 5). Crown diameter classification also revealed that more *B. aegyptiaca* trees were in 7-8.9 m crown diameter class (Figure 4c).

Table 5. Student t-test for the *B. aegyptiaca* tree characteristics

VARIABLE	MEAN	SITES COMPARED	MEAN	t	p	INFERENCE
DBH	(cm)					
Site A	30.508 ± 2.089	A vs B	8.60 8	2.998	0.01	**
Site B	21.9 ± 1.582					
HEIGHT	(m)					
Site A	8.13 ± 0.2969	A vs B	0.774	1.27	>0.05	NS
Site B	7.356 ± 0.595					
CROWN DIAMETER	(m)					
Site A	8.249 ± 0.7725	A vs B		2.105		
Site B	5.725 ± 0.9011		2.524		0.01	**

Key: * Extremely significant (p value < 0.001), ** Significant (0.01 > p value < 0.001), * Significant (0.05 > p value < 0.01) and NS Not significant (p value > 0.05)**

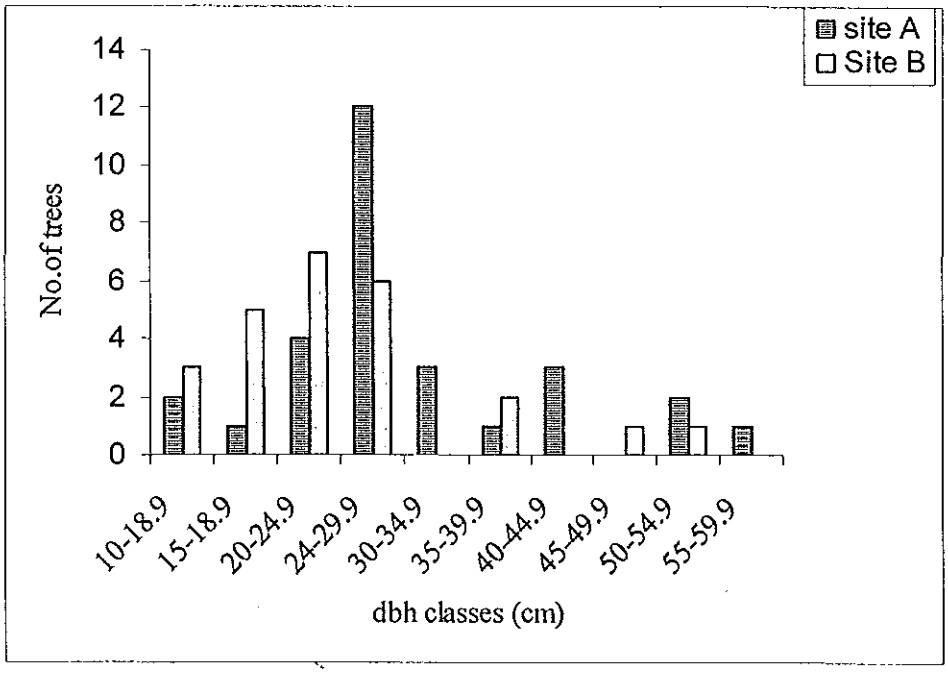

Figure 4a. *B. aegyptiaca* dbh classes

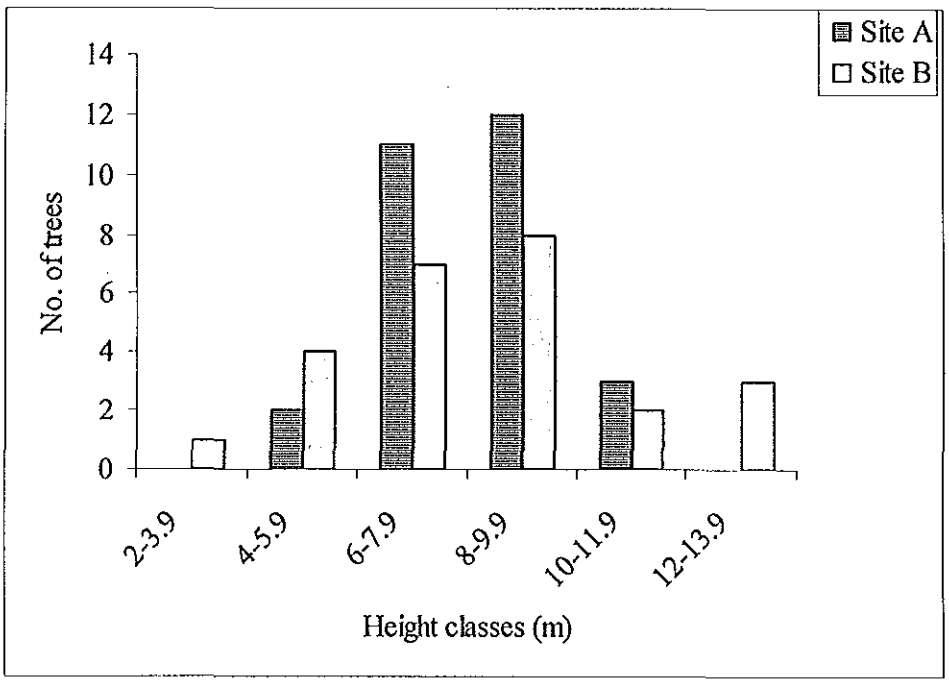

Figure 4b. *B. aegyptiaca* height classes

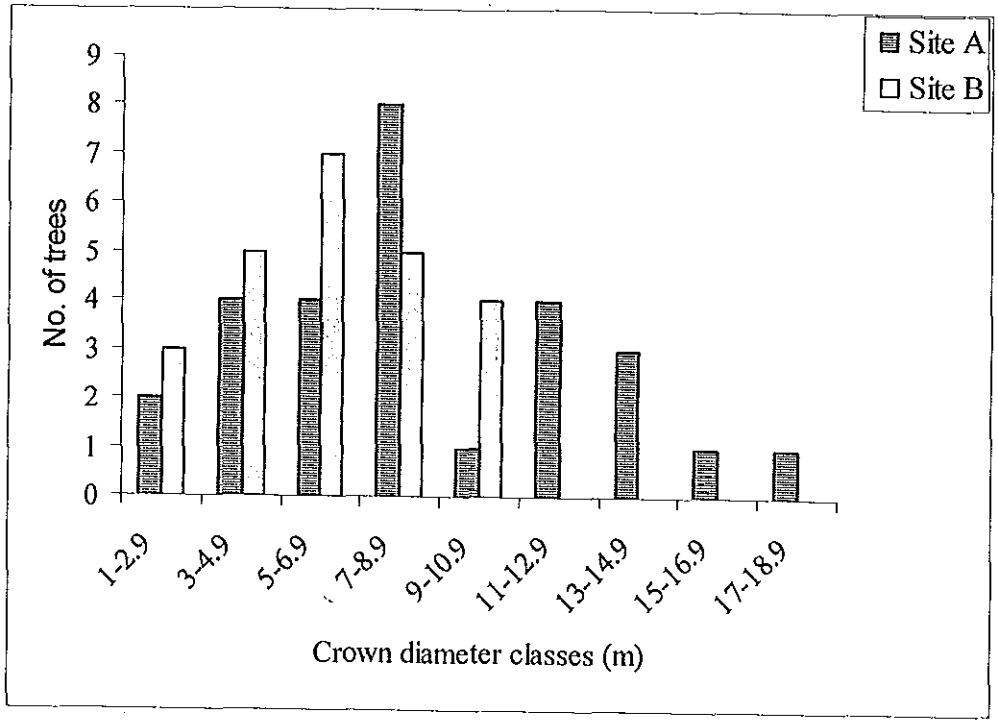

Figure 4c. *B. aegyptiaca* crown classes

4.2.3 Population of *B. aegyptiaca* trees in relation to other woody species

The distribution of tree species in terms of height, crown and dbh, varied in the three areas. Among the trees recorded in site B, *Acacia polyacantha* and *Lannea stuhlmannii* had lower densities. However, *A. polyacantha* and *Lannea stuhlmannii* had higher mean dbh, height and crown while *Rhus natalensis* had low mean dbh, height and crown diameter (Table 6).

Table 6. Distribution of trees dbh, height and crown diameter in a site where *B. aegyptiaca* coexists with other woody species

Tree species	Mean dbh (cm) ± SD	Mean crown diameter (m) ± SD	Mean crown diameter (m) ± SD
Lannea stuhlmannii	30.57 ± 0	13	13.5±0
Acacia polyacantha	30.57 ± 0	13.81±0	12.4±0
Balanites aegyptiaca	30.5 ±2.10	8.13 ±0.30	5.725±0.9011
Acacia tortilis	25.69 ± 2.40	12.03± 0.64	11.4±1.7
Acacia robusta	18.69 ± 3.5	8.29± 1.14	*7.21*±2
Acacia seyal var. fistula	18.63 ±1.12	10.5± 1.15	6.5±0.5
Acacia senegal	17.52 ±1.16	7.69 ± 0.5	*7.28*±0.7
Commiphora africana	17.2±1.36	5.65 ± 0.54	4.275±1.8
Lonchocarps eriochalix	15.12 ±0.80	5.65 ± 0.45	4.5±1
Acacia nilotica	14.15±2.80	6.84 ± 1.24	6.23±1.975
Grewia falax	12.86± 1.66	5.4± 0.4	3.2±0.3
Rhus natalensis	12.74±0	4.5 ± 0	2.5±0

5 DISCUSSION

5.1 Soil physicochemical properties

The texture of the soils of site A and B was dominantly clay, on the other hand, sand texture dominated at site C. The presence of high percentage of sand at site C may be attributed to weathering of the parent materials, which was predominantly sandstone. Another contributory factor could be movement of clay downwards during water infiltration.

Soil bulk density is a more dynamic property, which varies with structure, texture and organic matter content of the soil. The findings of the present study are not in agreement with those of Arshad *et al.*, (1996) which showed that bulk density increases with depth along the profile and ranges between 1.0 to 1.7 g/cm^3. High bulky density values above 1.8 g/cm^3 in top soils of the studied area might have been attributed to the trampling by wildlife to compaction. On the other hand, extremely low bulk density at site C (0.769 gcm^2) is attributed to high percentage of sand texture. Lyaruu *et al.* (2003), in their study on the relationship between edaphic factors and plant diversity in western Serengeti, Tanzania, recorded similar low bulk density at this site.

Increase in most soil parameters down the soil profile notably, sodium, potassium, calcium, magnesium, electrical conductivity and soil reaction (pH) suggests that the major source of the exchangeable bases was the parent rock and not organic matter which decreased down the profile. However, decrease in level of nitrogen and phosphorous down the soil profile indicates that the major source of the available nitrogen was the organic matter. This finding is also in line with Wild, (1993) and Brady (1994).

5.2 Correlation among the environmental factors

In the present study, positive correlation between organic matter and bulk density differed from the findings of Dagar *et al.* (1995). According to Dagar *et al.* (1995) bulk density negatively correlates with organic matter, and it increases down the soil profile. Positive correlation between organic matter and bulk density observed in the present study is attributed to the trampling by wildlife that causes compaction of soil.

Electrical conductivity was positively correlated with exchangeable bases, organic matter and clay texture. In sites where clay texture was dominant, leaching of cations could have been slowed down by attraction of cations to negatively charged cations exchange sites on clay and humus surfaces (McLean, 1978). On the other hand, negative correlation between salinity and sand could have been caused by both leaching and run off. Experience from the filed showed high erosion intensity at site where sand texture was dominant. These findings are therefore in agreement with those of Smith and Doran (1996) that clay loam soils are susceptible to salinization.

Significantly high correlation between organic matter and clay as shown in the present study was probably due to the tendency of organic matter to incorporate into soil aggregates (Cambell *et al.*, 1994). Also, high clay content contributes to better nutrient supply and water holding capacity that encourage dense vegetative cover which build up organic matter through leaf fall and litter accumulation (Stevenson, 1985). Although species diversity in the sites where clay dominated was relatively low as compared to the other sites, litter accumulation in these sites was very high. Litter accumulation was also enhanced by low erosion intensity in the sites where clay texture

dominated. On the other hand, relatively low organic matter percentages recorded in sites with higher percentages of sand is probably attributed to loss of humus through surface run off.

Nitrogen is the most common limiting factor for plant and microorganism growth since it is needed in higher concentration than other nutrients (Jarvis *et al.,* 1996, Brady and Weill, 1999). In the present study, there was no significant difference in nitrogen among the three sites. The results are not in agreement with Hatton and Smart (1984) since there was small negative correlation between nitrogen and organic matter. According to Jarvis *et al.* (1996) the quality of organic matter has substantial effect on mineralization and immobilization of nitrogen. High carbon/nitrogen ratio and lignin concentration in the litter commonly lead to nitrogen immobilization and hence low nitrogen availability, where as low carbon/nitrogen ratio and lignin concentration lead to nitrogen mineralization and high nitrogen availability. It is probable therefore that although the level of organic matter in site A was relatively high than that of site C, mineralization rate of nitrogen was low. Moreover, high pH values in the areas where percentage organic matter was relatively high may have reduced mineralization rate of nitrogen. Higher pH values enhance the conversion of mineral nitrogen to ammonia gas (NH_3), which is lost in the air (Brady and Weill, 1999).

Organic matter positively correlated with available phosphorous. This is probably due to the fact that high organic matter reduce phosphorous fixation in the soil (Brady and Well 1999). Also, negatively charged sites on clay colloides attract exchangeable bases to release fixed phosphorous. This increased percentage of available phosphorous in the sites where both organic matter and clay percentages were high.

5.3 Soil physical properties in relation to the distribution of *B. aegyptiaca*

A high percentage of clay in the site where a pure stand of *B. aegyptiaca* is found suggests both better fertility and water holding capacity. These attributes attract more species diversity (Donahue, 1995). Absence of other woody species in this site is attributed to other edaphic factors such as salinity, pH and compaction.

Soils in the site where a pure stand of *B. aegyptiaca* was found (Site A) had several attributes that hinder root growth. The first attribute is the presence of a restricting zone from 40 cm to 60 cm depth along the soil profile. The bulk densities of these soils were also relatively high. In few plots bulk density values above 1.8g/cm^3 were recorded. Bulk density has a direct influence on root growth and development for its contribution in soil compaction. It is reported that root penetration is totally hindered when bulk density exceeds 1.8 g/cm^3 (Arshad *et al.*, 1995). Successfully growth of *B. aegyptiaca* on such a compact soil suggests its tolerance nature to compact soils. This is probably a reason to why the species grows well in the water logged compact clay soils. Absence of other woody species in this site suggests their intolerance nature to soil compaction.

5.4 Soil chemical properties in relation to the distribution of *B. aegyptiaca*

According to Brady and Weill (1999) soils whose electrical conductance and pH values are above 1500 µS/cm and 8 respectively as reported at site A, are considered as saline. The absence of other woody species at site A was probably attributed to their low tolerance to saline soils as compared to *B. aegyptiaca*. Satisfactory plant growth in such saline soils depends on a number of interrelated factors including physiological constitution of the plant, its stage of growth and its

rooting habit (Brady and Weill, 1999). Growth of *B. aegyptiaca* in site A with such higher pH values is probably attributed to its well adapted physiological constitution and rooting.

Magnesium was found to have no significant influence on the distribution of *B. aegyptiaca*, although its concentration was relatively low in the areas where a dense stand of the species is found. In all sites concentration of magnesium recorded was above the minimum concentration below which plant growth is impaired ie 2.5meq/100g (Clarkson and Hanson, 1980). Of the elements found in the cytoplasm, magnesium has the highest chemical activity than other exchangeable bases (Clarkson and Hanson, 1980). Besides being one of the constituents of chlorophyll, magnesium is required in many enzymatic reactions. However, in the plant it is generally absorbed at lower quantity than potassium, sodium and calcium (Kirkby and Mengel, 1982).

In the present study, Cation Exchange Capacity (CEC) was not determined. However, more clay at site A where a dense stand of *B. aegyptiaca* is found suggests higher Cation Exchange Capacity (CEC) as compared to other sites since clay particles provide large surface area for the cations (Brady and Weill, 1999). This suggests that, the species grows well in fertile soils whose Cation Exchange Capacity is high.

It was statistically shown that there was no significant difference in the levels of nitrogen between the studied sites. In all sites levels of nitrogen recorded were above the minimum concentration below which plant growth is impaired ie 0.2 % (Leaf, 1973). On the other hand, level of phosphorous was significantly high in the sites where a pure stand of *B. aegyptiaca* was found indicating its significant correlation to the dense stand of *B. aegyptiaca.*

5.5 Population structure of *B. aegyptiaca* in Western Serengeti

Juveniles' *B. aegyptiaca* i.e. seedlings and saplings populations were relatively low as compared to tree population. This could have been attributed to both edaphic factors and anthropogenic dry season fires that cause stem mortality of small resprouting stems. The seed emergence from the greater depth is affected by soil thickness and compaction; which in turn can influence population dynamics of a particular plant (Lawrence, 1957). The small population of *B. aegyptiaca* seedlings in sites A and B may have been caused by clay, since soils with pronounced clay matrix hinders germination of buried seeds (Beneventus 2003).

The small saplings density as compared to tress density is an indication of poor recruitment potential of *B. aegyptiaca* in western Serengeti. This is probably attributed to mortality of juvenile *B. aegyptiaca* caused by both anthropogenic fire and browsing. In the present study, saplings were found to be more vulnerable to than seedlings.

Distribution curves of *B. aegyptiaca* tree dbh, height and crown diameter classes did not show a characteristic reversed "J" shapes. This is not a characteristic of natural forest (Luoga *et al.*, 2002) and is an indication of a population that faces the problem of declining. This could be attributed to both anthropogenic disturbances and grazing. According to Nkya (2003) the smaller trees (10 –20 cm dbh) are more preferred to larger ones by Ikoma people of western Serengeti in making hand tools. On the other hand, Claudius and Charles (1996) in their study in Tarangire National Park observed smaller trees to be more preferred by browsers than larger ones. Both scenarios could have led to the decrease in density of smaller *B. aegyptiaca* trees.

The mean average height of individual *B. aegyptiaca* trees did not show significant difference between the two sites where the species grows. However, the dbh and crown diameters of *B. aegyptiaca* trees were significantly higher where a pure stand of the species is found than where the species coexists with other wood species. Low dbh and crown diameter of *B. aegyptiaca* trees in the areas where the species coexists with other woody species is probably attributed to competition for resources such as nutrients and light. According to Rhoades (1997), plant competition for resource and light results into thinning and lengthening tendency of the trees. In the present study, it has been revealed that, with moderate density, *B. aegyptiaca* trees have high mean dbh and crown diameter even when the soil is very poor.

5.6 The influence of *B. aegyptiaca* on herbaceous and grass species

Herbaceous and grass species diversity under the canopy of *B. aegyptiaca* was significantly higher than outside the canopy. This is attributed to the ability of *B. aegyptiaca* to create a good microclimate under its canopy to attract more grass and herbaceous species as reported Asferachew *et al.*, (1998). Growth of species such as *Achyranthes aspera, Aristida barbicollis, Asparagus africana, Ormocarpum kirkii, Grewia trichocarpa, Maerua edulis, Ageratum conyzoides, Commelina africana and Commelina bengalensis* which were only recorded under the canopy of *B. aegyptiaca* tree at site A, probably suggests the ability of the study tree to reclaim soil salinity.

6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study reveals that, the distribution pattern of *B. aegyptiaca* in western Serengeti is significantly influenced by edaphic factors. The edaphic factors notably, soil pH, clay, sand, electrical conductivity (EC) and exchangeable bases (sodium, potassium and calcium) positively correlate with dense stands of *B. aegyptiaca*. On the other hand relatively high percentages of sand fraction and magnesium concentration negatively correlate with high densities of *B. aegyptiaca.*

The study shows *B. aegyptiaca* to be tolerant to saline conditions. This is a reason to why it is a dominant woody species in waterlogged saline soils of Western Serengeti. The soils that support a pure stand of *B. aegyptiaca* are characterized by high electrical conductivity and pH values indicating ability of the species to colonize massive waterlogged areas of western Serengeti. Its ability to survive in soils with high pH levels is probably attributed to its well adapted physiology and rooting habit. Therefore, *B. aegyptiaca* can be conveniently regarded as a halophytic plant.

The ability of *B. aegyptiaca* to grow in compact soils where no other woody species can withstand suggests its survival strategy in the drylands. The ability of *B. aegyptiaca* to flower and fruit even during the driest years is attributed to this exceptional survival strategy in the drylands.

As revealed in the present study, the population of *B. aegyptiaca* in western Serengeti is facing a problem of declining. The smaller density of *B. aegyptiaca* saplings as compared to both seedlings and trees populations suggest high vulnerability of saplings.

6.2 Recommendations

Although it has been concluded in this study that *B. aegyptiaca* is tolerant to soil compaction, studies on anatomic and rooting habit of the species are recommended to further understand its ability to survive in drylands. Intensive soil bank studies in the sites where *B. aegyptiaca* grows are recommended to give clear population dynamics of the species.

Balanites aegyptiaca has a lot of values although its ethnobotanical information in Tanzania is not documented. It is recommended therefore that, the ethnobotanical information of this very important plant species in the drylands be documented to support justification of its conservation strategies so as to save it from threats.

Experience from the field has shown a significant anthropogenic pressure on *B. aegyptiaca* especially in unprotected areas. In the protected areas, pressure from browsers such as elephant is also significant. The propagation studies towards conservation of *B. aegyptiaca* are therefore highly recommended before the situation becomes worse.

Most soils in the drylands are saline since rainfall is not enough to leach out accumulating basic forming cations. However, the growth of several salinity intolerant herbaceous species under the canopy *of B. aegyptiaca* suggests the probability of the species to reduce salinity to a level that supports the survival of these species. There is a pressing need of studying the potential of *B. aegyptiaca* to reclaim sodic and saline soils, since most of the soils in the drylands suffer from salinity.

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8 APPENDIX

Plant species recorded during field data collection in Western Serengeti

Plant species	Family	Site A	Site B	Site C
Acacia drepanolobium Sjost	Mimosaceae	-	+	-
A. nilotica (L) Del	Mimosaceae	-	+	+
A. polyacantha Willd	Mimosaceae	-	+	-
A. robusta Burchell	Mimosaceae	-	+	-
A. senegal (L) Willd	Mimosaceae	-	+	+
A. tortilis (L.) Wild	Mimosaceae	-	+	-
A.seyal var. fistula Del.	Mimosaceae	-	+	-
Acacia seyal Var. Seyal Del.	Mimosaceae	-	-	+
Acalypha indica L.	Euphorbiaceae	-	+	-
Aerva lanata (L) Juss.	Amaranthaceae	-	+	+
Ageratum conyzoides L.	Compositae	+	+	+
Albizia petersiana (Bolle) Oliver	Mimosaceae	-	-	+
Albizia amara (Roxb) Boivin	Mimosaceae	-	-	+
Aloe secundiflora Engl.	Liliaceae	-	-	+
Achyranthes aspera L.	Amaranthaceae	+	+	-
Amaranthus graecizans L.	Amaranthaceae	+	-	-
Amaranthus hybridus L.	Amaranthaceae	-	+	-
Anthericum cameronii Bak.	Liliaceae	+	-	-
Aristida barbicollis Trin & Rupr.	Poaceae	+	+	-
Aristida hordeaceae Kunth	Poaceae	+	+	-
Asparagus africanus Lam.	Liliaceae	+	+	+
Asparagus ethiopica Lam.	Liliaceae	-	-	+
Asparagus falcatus L.	Liliaceae	-	+	+
Astripomoea malvacea (Klotzsch) Meeuse	Convolvulaceae	-	+	-
Balanites aegyptiaca (L) Del.	Balanitaceae	+	+	-
Becium angustifolium (Benth) N. E. Br.	Labiatae	+	+	+
Blepharis linariifolia Pers.	Acanthaceae	-	-	+
Bidens pilosa L.	Compositaceae	-	+	+
Brachiaria brizantha (A. Rich) Stapf	Gramineae	+	+	+
Blephalis maderaspatensis (L.) Roth	Acanthaceae	-	+	-
Cadaba farinosa Lam.	Capparaceae	+	+	-
Capparis tomentosa Lam.	Capparaceae	-	+	+
Cassia mimosoides (L.) Greene	Caesalpiniaceae	-	+	+
Catunaregam spinosa (Thunb) Tivengadum	Rubiaceae	-	-	+
Cenchrus ciliaris L.	Gramineae	+	+	+
Chlorophytum bakeri Poelln.	Liliaceae	+	-	-
Cissus rotundifolia (Forsk.) Vahl	Vitaceae	+	-	-

Appendix continues

Plant species	Family	Site B	Site B	Site C
Combretum molle G. Don.	Combreteceae	-	-	+
Combretum zeyheri Sond	Combreteceae	-	-	+
Commelina africana L.	Commelinaceae	+	+	+
Commelina bengalensis L.	Commelinaceae	+	+	+
Commelina subulata Roth	Commelinaceae	+	+	+
Commiphora africana (A. Rich) Engl.	Burseraceae	-	+	+
Crabbea velutina S. Moore	Acanthaceae	-	+	+
Crinum papillosum L.	Amarylliadaceae	-	+	+
Craterostigma hirsutum S. Moore	Scrophucariaceae	+	+	+
Crotolaria laburnoides Klotzsch	Papilionaceae	-	+	+
Crotolaria spinosa Benth.	Papilionaceae	-	-	+
Chloris gayana Kunth	Poaceae	-	-	+
Clerodendrun myricoides (Hochst.) Vatke	Labiatae	-	-	+
Cynodon dactylon (L.) Pers.	Poaceae	+	+	+
Cyanotis foecundra Harsk	Commelinaceae	+	-	-
Cycinium tubelosum (L.f.) Engl.	Scrophulariaceae	-	+	-
Cyperus obtusflorus Vahl	Cyperaceae	+	+	_
Cyphostema adenocaule (A. Rich) Wild	Vitaceae	-	-	+
Dichrostachys cinirea (L.) Wight. & Arn.	Mimosoideae	+	-	+
Dichanthium annulatum (Forssk.) Stapf	Poaceae	+	+	+
Digitaria abyssinica (A. Rich.) Stapf	Poaceae	+	+	+
Digitaria macroblephara (Hack.) Stapf	Poaceae	+	+	+
Dolichos oliveri Schweinf.	Papilionaceae	-	-	+
Dombeya cincinata (Hochst) Planchon.	Sterculiaceae	-	-	+
Duosperma crenatum (Milnes-Redh) Npper	Acanthaceae	+	-	-
Enicostema axillare (Lam.) A. Rayamal	Gentianaceae	-	-	+
Eragrostis racemosa (Thunb.) Steud.	Poaceae	-	+	+
Erythrina abyssinica DC.	Papilionaceae	-	-	+
Ethulia conysoides L.	Compositae	-	+	+
Euclea racemosa Murray	Ebenaceae	-	-	+
Euphorbia hirta L.	Euphorbiaceae	-	+	-
Eustachys paspaloides (Vahl) Lanza & Mattei	Poaceae	-	+	-
Ficus sycomorus L.	Moraceae	-	-	+
Fimbristylis burchellii Fic. & Hiern	Cyperaceae	-	-	+
Flueggea virosa (Roxb. Ex Wild) Bailon	Euphorbiaceae	-	+	+
Gardenia volkensii K. Schum.	Rubiaceae	-	-	+
Grewia bicolor Juss.	Muntingiaceae	-	-	+
Grewia fallax K. Schum.	Muntingiaceae	-	+	+

Appendix continues

Plant species	Family	Site A	Site B	Site C
Grewia trichocarpa A. Rich.	Muntingiaceae	+	+	+
Gutenbergia rueppellii Sch. Bip.	Compositae	+	+	-
Harpachne schimperi A. Rich.	Poaceae	-	+	+
Harrisonia abyssinica Oliver	Simaroubaceae	-	+	+
Heliotropium steudner Vatke	Boraginaceae	-	+	-
Heteropogon controtus (L.) Roem & Schult	Poaceae	-	-	+
Hibiscus cannabinus L.	Malvaceae	+	+	+
Hibiscus surattensis L.	Malvaceae	+	-	+
Hoslundia opposita Vahl	Lamiaceae	-	-	+
Hyparrhenia filipendula (Hochst) Stapf	Poaceae	-	+	+
Indigofera volkensii Taub.	Papilionaceae	+	+	+
Ipomoea sinensis (Desr.) Choisy	Convolvulaceae	+	+	+
Jasminum fluminese Vell.	Apocynaceae	-	-	+
Kigelia africana (Lam.) Benth.	Bignoniaceae	-	-	+
Lannea humillis (Oliver) Engl.	Anacardiaceae	-	+	+
Lannea schimperi (Hochst ex A. Rich) Engl.	Anacardiaceae	-	-	+
Lannea stuhlmannii (Engl) Engl.	Anacardiaceae	+	+	+
Loudetia simplex (Nees) C.E. Hurbbard	Poaceae	-	-	+
Leonotis nepetifolia R. Br.	Lamiaceae	+	-	+
Leucas diflexa L.	Lamiaceae	-	+	+
Lippia javannica (Burn. F.) Spreng.	Verbenaceae	-	+	+
Lonchocarps erichalix Harms	Papilionaceae	-	+	+
Microchloa kunthii Desv.	Poaceae	+	+	+
Maerua edulis DC.	Capparaceae	+	+	+
Rhynchelytrum ripens (Wild) C.E.	Poaceae	-	+	+
Maytenus senegalensis (Lam.) Exell	Celastraceae	-	+	+
Monechma debile (Forsk) Nees	Acanthaceae	+	+	+
Monsonia angustifolia A. Rich.	Geraniaceae	+	+	+
Mycrotyloma axillare (E. Meyer) Verdc.	Papilionaceae	-	-	+
Nesaea schinzii Koehne	Onagraceae	-	+	-
Oldelandia herbacea (L.) Roxb.	Rubiaceae	+	+	-
Ormocarpum kirkii S. Moore	Papilionaceae	+	+	+
Ormocarpum trichocapum (Taub.) Engl.	Papilionaceae	+	+	+
Ocimum basillicum L.	Lamiaceae	-	-	+
Ocimum suave Willd.	Lamiaceae	-	-	+
Ozoroa insignis Delile	Anacardiaceae	-	-	+
Panicum astrosanguineum A. Rich.	Poaceae	+	+	+
Panicum coloratum L.	Poaceae	+	+	+

Appendix continues

Plant specie	Family	Site A	Site B	Site C
Panicum maximum Jacq.	Poaceae	-	+	+
Parinari curatelifolia Planchon ex Benth.	Chrysobalanaceae	-	-	+
Pennisetum polystachion (L.) Schult.	Poaceae	-	+	+
Piliostigma thonningii Schumacher	Caesalpiniaceae	-	-	+
Pogonarthria squarrosa (Roem & Schult) Pilg.	Poaceae	-	-	+
Pseudovigna argentea (Wild) Verdc.	Papilionaceae	-	-	+
Rhynchosia resinosa (A.Rich) Bak.	Papilionaceae	-	-	+
Rhynchosia hirita (Andrews) Meikle & Verdc.	Papilionaceae	-	-	+
Rhoicissus tridentata (L. f.) Wild & Drummond	Vitaceae	-	-	+
Rhus natalensis Bernh.	Anacardiaceae	-	+	+
Rhus vulgaris Meikle	Anacardiaceae	-	-	+
Rhynchosia minima (L.) DC.	Papilionaceae	+	+	+
Rubia cordifolia L.	Rubiaceae	-	-	+
Ruellia patula Jacq.	Acanthaceae	+	+	+
Ruellia postrata T. Anders	Acanthaceae	+	+	+
Sansevieria eherenbergil Bak.	Hypoxidaceae	+	-	-
Sclerocarya birrea Sand.	Anacardiaceae	-	+	+
Senecio abyssinicus Sch. Bip.	Compositae	-	+	+
Setaria homonyma (Steud.) Chiov.	Poaceae	-	-	+
Setaria sphacelata (Schumach.) Moss	Poaceae	+	+	+
Scutia myrtina (Burm. F.) Kurz	Vitaceae	-	-	+
Sida acuta Burm.	Malvaceae	+	-	+
Sida alba L.	Malvaceae	-	+	+
Solanum incanum L.	Solanaceae	+	+	+
Sphaeranthus suaveolens (Forsk.) DC.	Compositae	-	-	+
Sporobolus fimbriatus (Trin.) Nees	Poaceae	-	+	+
Sporobolus stapfianus Grand.	Poaceae	+	+	+
Striga asiatica (L.) Ktze	Scrophulariaceae	-	+	-
Strychnos spinosa Lam.	Loganiaceae	-	-	+
Tagetes minuta L.	Compositae	+	-	-
Tephrosia villosa (L.) Pers.	Papilionaceae	+	-	+
Terminali mollis Laws.	Combretaceae	-	-	+
Themeda triandra Foresk	Poaceae	+	+	+
Thunbergia alata Sim	Acanthaceae	-	-	+
Tragia fuliaris Boj.	Euphorbiaceae	-	-	+
Vernonia adoensis Walp.	Asteraceae	-	-	+
Vernonia poskeana Walp.	Asteraceae	-	+	-
Vitex fischeri Gurk	Verbenaceae	-	-	+

Appendix continues

Plant specie	Family	Site A	Site B	Site C
Ximenia caffra Sonder	Olacaceae	-	-	+
Zaleya petandra (L.) Jeffrey	Aizoaceae	-	+	+
Ziziphus mucronata Wild	Rhamnaceae	-	-	+
Zornia setosa Bak.	Papilionaceae	+	+	+
Total	**43**	**56**	**89**	**122**

Key: + Presence of the species and - Absence of the species