PRODUCTIVITY AND CONSEVATION PRACTICES FOR *BALANITES AEGYPTIACA* (DESERT DATE) IN NAPAK WOODLANDS

BY

ENGAMVILE JOEL

214016243

A RESEARCH REPORT SUBMITTED TO THE SCHOOL OF FORESTRY, ENVIRONMENTAL AND GEOGRAPHICAL SCIENCES IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF A BACHELOR DEGREE IN SOCIAL AND ENTREPRENEURIAL FORESTRY OF MAKERERE UNIVERSITY

OCTOBER, 2018

DECLARATION

I Engamvile Joel, hereby declare that this is true outcome of my thesis produced during and after the research study from Napak woodland in Napak district and it has never been submitted to any institution of higher learning for partial fulfillment for the award of any certificate, diploma, and or a degree.

Signature:………………………………… Date 19/10/2018

This report has been supervised and submitted with approval of the following supervisors;

Field Supervisor

Director of Nabuin Zardi: Dr. OKULLO PAUL

Signature………………………………… Date 25/10/18.

Academic Supervisor: Prof. John Bosco Lomoris Okullo.

Signature ………………………………… Date 17/10/2018

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ACRONYMS/ SYMBOLS

AGC - Above Ground Carbon

C - Carbon

CD - Crown Diameter

Cm - Centimeter

DBH - Diameter a Breast Height

Ha - Hectare

IFTs - Indigenous Fruit Trees

IUCN - International Union of Conservation Nature

MMB - Mixed Method Design

RBS - Randomised Branch Sampling

UNFCCC - United Nation Framework Convention on Climate Change

DEDICATIONS

To my beloved parents, Osole Gordon and Leleru Grace, my lovely Siblings (Family members) for your support and encouragement and bearing with me in the due course of my entire school life most especially during data collection, which kept your hearts punched for being far in Karamoja.

To my Beloved friends Luyiga Jane, Molly Kuteesa, my field Assistants Mark John Kodet and family for bearing with me in total unity during data collection most especially when things looked impossible, you and all forestry students especially those that shared and encoded me with necessary knowledge

ACKNOWLEDGEMENT

During my research, a number of people, organization played great roles towards accomplishing this thesis. My foremost appreciation goes to my Academic supervisor Prof. John Bosco Lomoris Okullo for the efforts rendered, patience, time offered to me from year one and also help me come up with such a thesis. Our absolute intellectual ability and thinking has shaped my ecological thinking during the scope of my studies.

On highly special note, I would like to thank the director of Nabuin ZARDI, Dr. Okullo Paul whose interest on productivity of *Balanites aegyptiaca* in Napak woodland led to the finding of my Bachelors thesis, it is due to his absolute keen interest in this woodland that I got this unforgettable opportunity. Many thanks again Doctor, for your parental care, financial support and encouragements.

My field assistants, Mr. Kodet John Mark and Trinity. Your indigenous knowledge, commitment and good humor helped me to accomplish my data collection both in Kololechel and Iriiri Sub-counties. Many thanks,

My appreciation goes to the Family of Mr. Kodet, the Wife, Daughters Michele and Maurine for their kind reception, care and accommodation you offered me during data collection. Many thanks.

Many thanks to the kindness of all staff members of Nabuin ZARDI for your invaluable support both in kind and material, especially for accepting and treating me as a staff member during my stay at the institute while I was collecting data.

My appreciation goes to my beloved friends, Nasasira Andrew, Natwuijuka Brian, Jane Luyiga, Koi Eveline and Okwele Sam for again your invaluable material support and encouragements. Please dears, all your support has contributions to the completion of this thesis.

With due respect, I would like to extend my appreciation to my Brother and friend, Mr. Malunga Gabriel for the intellectual and material support rendered to me during the writing of this thesis. Your efforts are invaluable. Many thanks Brother.

With great honor, I would like to extend my appreciation to my fellow research colleagues at School of Forestry, Environmental and geographical sciences with whom I interacted and were supportive during the writing of this thesis

I am thankful to the school of forestry, Environmental and Geographical sciences for implementing such crucial and a fundamental course unit which really speaks and justifies the actual daily life in the world of science, science is all about research, to finding the unknown and improving on the known.

Lastly but not least, To all of you that I have **mentioned** and those at heart, staff of Forestry, Makerere University, I will never forget your invaluable support and involvement in this chain of this challenging scope of my research. May Almighty God keep blessing and rewarding the work of your Hands. Those spirits are the real meaning of **“We Build for the Future”**

FOR GOD AND MY COUNTRY

ABSTRACT

B. aegyptiaca is economically and ecologically important Indigenous Fruit Trees in the dry savanna woodlands across Africa. The local communities have used it for generations. The tree has immense contribution to livelihoods and amelioration of micro climate where *B. aegyptiaca* occurs. Despite it being ranked among lost priority crops, there is no clear understanding of *B. aegyptiaca* productivity and conservation strategies under different land uses in Karamoja sub-region and Napak woodland in particular. The specific objectives of the study were to: examine size class distribution of *B. aegyptiaca,* to quantify fruit productivity on different landscapes of the woodland, estimate amount of Above Ground Carbon (AGC) that can be sequestered by *B. aegyptiaca* and to assess local conservation strategies for *B. aegyptiaca* in Napak woodland. All Dbh of *B. aegyptiaca* ≤5cm was measured in all the 100x150 plots. The size classes were described using size class distribution, densities and their slopes. *B. aegyptiaca* density was influenced by land management regimes. Current crop fields registered high tree density (ha^{-1}). Productivity and activity in *B. aegyptiaca* begins when individuals reach approximately ≤7cm Dbh. Full fruit production levels (mean: 12-12,288) are reached in *B. aegyptiaca* trees at <25 cm Dbh. Desert date trees in ≥10cm dbh class sequestered mean carbon of 5.22Mg C ha^{-1}, those in 10-19 cm dbh class sequestered 63.16±66.8 Mg C ha^{-1}, 30-39 cm dbh class sequestered 278.94±50.0Mg C ha^{1} and <50 cm dbh sequestered 1168.8±694.6Mg C ha^{-1}. This study confirms that together with environmental factors, Land management regimes are the major factors in influencing productivity and stands management of *B. aegyptiaca* in Napak woodland. Since human impacts adversely affect desert date stands of ≥20cm Dbh classes, there should be fire exclusion or better fire management options to fully maintain productive stands of desert date, early dry season burning is recommended for fallow and productive stands to improve yields. Future in depth study on productivity and management practices of *B. aegyptiaca* should include young individuals (≥5cm) from the point of seed germination within the main land use types so as to clarify survival and mortality rates of both regenerating shoots and old individuals. Study on reproduction comparing the response to pollen from distant sources (probably <1km up to 10 km) is recommended.

CHAPTER ONE

INTRODUCTION

1.1 Background

In sub-Saharan Africa, trees are preserved because of the numerous derived benefits such as food, wood, fodder, medicine, climatic amelioration and boundary markers (Boffa, 1995). Such trees in the savannas can occur naturally or as a result of edaphic features, and fire in the absence of cultivation. In these woodlands, the woody vegetation is altered in composition and density in order to facilitate its use. Most often, woodlands are not the product of a single growing season, but a reflection of a slow development process and tree growth over one or several decades.

Indigenous woody plants in these savanna woodlands such as *B. aegyptiaca*, also known as desert date trees, are critical to the social and economic systems of survival in most rural areas. Both timber and non-timber products from these forests are important for food security due to their variety and availability during different periods of the year and because of their significant potential for livelihood improvement (Teklehaimnot, 2004).

Being a multi-purpose species, *B. aegyptiaca* offers a good chance to be conserved by locals, as they already know its benefits. This reduces their dependence on the natural forest where the species can be conserved (Dawson, 1997). The economic importance of *B. aegyptiaca*, 'Ekorette' (Akarimojong) tree to the local people of the Karamoja sub-region is evidenced by the protection traditionally accorded the trees from the ravages of fires within the crop fields. In Uganda, the Madi, Iteso, and Karamojong have long-standing traditions that involve different parts of the *B. aegyptiaca*, particularly the fruits and biomass. In this region, *B. aegyptiaca* is used for various purposes such as fodder, medicines, charcoal (Egweru *et al.*, 2014b) and the almond is rich in saturated fatty acids that are used as cooking oil (NRC, 2008). It is one of the most affordable and widely used sources of food in the arid and semi-arid regions of Africa like Karamoja where other options are few (NRC, 2008).

The fruits and other products of *B. aegyptiaca* are obtained from the unmanaged trees in the wild especially during the five months of food scarcity (November to March) (Egweru et al., 2014) and there are no traditions of planting because the species takes about 5-12 or more years to first bear fruits (Hall *et al.*, 1996). Even then, farmers usually protect desert date trees when they clear their fields because of the values they cherish in it (Hall *et al.*, 1996). The few protected trees in cleared fields do thrive due to protection from seasonal fire, livestock, and competition from surrounding woody plants and the trees often develop into larger trees than those found in the natural woodland (Okia, 2005).

Although the existing *B. aegyptiaca* populations in Napak woodland are essentially unmanaged with the uncontrolled annual harvests of these wild indigenous trees, these woodlands are recognized as basic components for ensuring sustainable development if well managed (MWLE, 2000). Since the woodland containing *B. aegyptiaca* as an indigenous trees is one of the most important terrestrial biomes that greatly contribute and play a huge role in regulating climate related cycles (Nasi *et al.*, 2002), there is a global concern in understanding such woodland eco-system (Walker *et al.,* 2004) in terms of their productivity in the dry land regions like Karamoja. Since many woody species in tropical and subtropical areas particularly those with multipurpose uses involving fruits such as *B. aegyptiaca*, are threatened as sustainable resources by habitat alteration and over use.

Initiation of viable local conservation strategies for *B. aegyptiaca* are thus, required at both local and national levels before its ecological integrity is lost through woodland degradation. In order to develop a conservation strategy for *B. aegyptiaca*, a formal study emphasizing its spatial population structure, regeneration capacity and Phenological patterns is vital besides, local community's indigenous knowledge.

1.2 Problem statement

According to Egweru *et al* (2014) *B. aegyptiaca* as an indigenous tree species is highly preferred and utilized throughout the year most especially during the 5 month pangs of hunger for food (leaves for vegetables) medicine, live fences, fodders and fuel wood for subsistence living in this area. Despite the fact that *B. aegyptiaca* is an extremely important tree species in the development of the subsistence rural economy in Karamoja region, its potential use is not yet entirely known. Apart from some initiatives in northern Uganda by (Okia *et al.*, 2011) and Egweru (Egweru *et al*., 2014), no specific study has been carried out in Karamoja region to establish productivity potentials and conservation strategies of *B. aegyptiaca.*

This huge gap has also hindered the development of appropriate propagation and management techniques for enhancing the productivity of *B. aegyptiaca* and its conservation in Karamoja sub-region.

1.3 Aim and Objectives

1.3.1 Aim

The aim of this study was to determine the fruiting productivity and conservation strategies for *B. aegyptiaca* in Napak woodlands.

1.3.2. Specific Objectives

The specific objectives of the study were:

i) To examine size class distribution of *B. aegyptiaca* in Napak woodland.

ii) To quantify fruit productivity of *B. aegyptiaca* on the different landscapes of the Napak woodland.

iii) To estimate amount of above ground carbon (AGC) that can be sequestered by *B. aegyptiaca* in selected sites of Napak woodland.

iv) To assess local conservation strategies for *B. aegyptiaca* in Napak woodland.

1.4. Research Question

The following research questions were posed:

i) What is the size class distribution of *B. aegyptiaca* in Napak woodlands?

ii) What is the fruiting potential of *B. aegyptiaca* in terms of branching probability?

iii) How much above ground carbon can *B. aegyptiaca* sequester or sink in the selected sites of the woodland?

iv) What are the local conservation practices and opportunities for conserving *B. aegyptiaca* in Napak woodland?

1.5 Justification/Significance of the Study

Since most of woodland habitats where *B. aegyptiaca* are located outside protected areas (NEMA, 2000), appropriate integrated conservation and development strategies need to be put in place. However, such integrated conservation and development strategies cannot be realized unless detailed knowledge of its productivity and conservation strategies is available (Okullo *et al.*, 2004). This is so because, understanding the productivity and conservation strategies for *B. aegyptiaca* in Napak woodland can provide very useful information for promoting its conservation and sustainable use (Schongart *et al.*, 2000), especially in developing countries like Uganda that has high poverty levels as well as where peoples livelihoods depend entirely on forest resources (NEMA, 2000).

When implemented, recommendations from such studies can also contribute to eradication of poverty and hunger, improving environmental sustainability. This in turn can contribute to the achievement of the Sustainable Development Goals (SDGs) aimed at reversing loss of biodiversity, increasing forest coverage, reducing carbon emission and increasing proportion of species threatened with extinction. By availing information on fruit production of *B. aegyptiaca* tree, this study has provided useful information that can be used to promote selection and establishment of *B. aegyptiaca* plantation. On the Academic point of view, the study has equipped me with relevant academic knowledge, skills for proposal development and love for research and it is from this study, I will also obtain my Academic degree in Social and Entrepreneurial Forestry of Makerere University.

1.6 Scope of the study

This study was limited to Napak woodlands with Iriiri parish as the study site respectively. The content scope focused on the productivity and conservation practices for *B. aegyptiaca* in Napak woodland, estimation of its fruit production potential and quantification of the Above Ground Carbon (AGC) can be sequestered by *B. aegyptiaca* in the selected sites of the woodland.

CHAPTER TWO

LITERATURE REVIEW

2.1 *Balanites aegyptiaca* Tree

B. aegyptiaca (desert date) is an indigenous tree species (commonly known as Ekorette) belonging to the family zygophyllaceae (NRC, 2008), it grows in the semi-arid areas to sub humid savanna areas (NRC, 2008). Desert date is found on varied soils, it prefers valley soils but will grow in sand, sandy loams, clays, cracking clay, black cotton, alluvial, gravelly, and stony soils (RSCU, 1992). *B. aegyptiaca* is also known to tolerate heavy clay soils (Teel, 1984).

Ecologically, the tree species is very flexible with excellent persistence to withstand occasional flooding and is adaptable to a wide range of sites (NRC, 2008) and climatic conditions, although it cannot tolerate prolonged waterlogging (NRC, 2008). It has good drought tolerance (Hall, 1991) and is not damaged by grass fires (except young trees), due to it having a deep tap root and thick bark. It invades areas having periodic fires and areas with heavy livestock activity like dry tropics of Karamoja. Young plants have counted leaf number that emerge along the rachis and from the base of the thorns and are fairly termite resistant. Due to the multi-purpose function, its fine grain, and ability to be easily worked into a good polish, the tree has become very susceptible to multiple uses (Egweru et al., 2014).

Plate 1: A typical stand of B. aegyptiaca at maturity in Iriiri Parish

According to Sands (2001) and Vgot (1995), the tree is distributed in arid and semi-arid zones of tropical Africa which is native to Algeria, Angola, Senegal, Benin, Burkina Faso, Burundi, Cameroon, Chad, Democratic Republic of Congo, Djibouti, Eritrea, Ethiopia, Libyan, Morocco, Myanmar, Nigeria, Saudi Arabia, Somalia, Tanzania, Uganda and Republic of Zambia extending to Zimbabwe.

It has been suggested that 10- 30+ years are required before full production is reached and that fruit production increases until the age of 60+ years, although the mature tree may live up to about 100 or more years (Sonau et al., 2006). B. aegyptiaca is normally a slow growing, small to medium mid-sized tree; its size is apparently largely controlled by external conditions (Hall et al., 1996). Where subject to regular fire, height rarely exceeds 10-15 m, while under protection; individuals may be as tall as 15+ m. Heights of 15-20 m are typical in annually cultivated fields (Hall et al., 1996). The tree is much branched, forms a dense topping stout bole of some 4 m (Plate 3). Branching is heavy with a number of large, gnarled, wide spreading limbs (Plate 3).

The bark is easy to recognize with brownish-dark color, thick and rough and fissured into raised rectangular scales like a crocodile skin. The leaves are clustered along and at the ends of branches covered with scars (Aubreville, 1964). Young leaves in Desert date are usually initially yellowish-green becoming smooth, dark green and thick when mature. In shape, the lamina is concave (about 5-8 cm long) with a rounded tip and with the base narrowed to a stalk about 0.5-1cm. The woody associates of *B. aegyptiaca* are often species locally valued and maintained by the local people with extensive indigenous knowledge (Hall *et al.,* 1996) It is often found in association with woody species such as Acacia family (Hall *et al.* 1996) and as extensive stands on wooded farmlands (Okia, 2005).

2.2. Factors affecting Size-class Distribution of Indigenous Tree Species

The population status of a species is indicated by its spatial and size class (or age) structure. Knowledge of the distribution/structure of the populations is of considerable importance in the management of any species or forest in general. It represents knowledge of the amount of resource available, its distribution and its characteristics, and of changes occurring in them. Awareness of trends of change provides a picture of the future prospects of the resource and can indicate how it might be managed in a sustainable way (Byakagaba, 2011). When regeneration of a species is severely limited and seedlings die before becoming established (Whitmore, 1975), a size class distribution with pronounced absence of saplings and juveniles is observed as opposed to a stable, continually, self-maintaining population characterized by a progressive decrease in the number of individuals from the smaller to large size classes, with the intermediate classes being well represented (Okullo *et al.,* 2004). It follows that variation in size class distribution can occur between populations. Morphological characteristics of trees may also vary within populations as well as between them (Okullo *et al.*, 2004).

Several factors, biotic and abiotic; influence size class distribution and morphological characteristics existing within and between populations.

Plate 2: Scattered B. aegyptiaca tress in Napak woodland

The major abiotic factors influencing size class distribution include water and nutrient availability, soil acidity/alkalinity, soil salinity, and presence of heavy metals in the soil, and extremes of temperature. The major biotic factors involve the degree of exposure of the population to disturbances such as fire, browsing, and other human impacts (Okullo *et al.,* 2004) Since most tree species in parklands (like *B. aegyptiaca*) are multi-functional, their structure and distribution patterns are intimately related to human influences (Okia, 2005). Tree species composition and density in the parklands also depend on ecological and sociological factors such as the density and diversity of trees in the original vegetation, the attitude of people towards trees, agricultural practices and the importance and management of livestock (Pullan, 1974).

In savanna parklands, there is high degree of impact of human selection on parkland formations and farmers tend to reduce the total numbers of stems and species, retaining only those preferred (Boffa, 1999). Tree selection and conservation are closely linked to agricultural production activities over a span of years/decades and their specific management influences the spatial structure of parklands. Not only are parkland composition and structure the result of the type and management intensity of agricultural activities, but they are also influenced by demographic changes (e.g. wars as for Karamoja region), which makes an area devastated, exploitative woodcutters and herdsmen, settlement and assisted regeneration (Boffa, 1999).

Even if there has been a general disagreement about the importance of natural (e.g. drought) versus human and livestock influences as factors responsible for the absence of tree regeneration in the parklands (Okullo *et al.,* 2004), an analysis of data available on natural regeneration in the Sahel region showed that both aspects are involved. Where moisture availability is low and regeneration poor, livestock are likely to remove all available regeneration. Where moisture is adequate, sufficient young plants survive even under intense grazing (Kessler & Breman 1993).

The degree of exposure of a site to fires, browsing and such human impacts as pasture expansion, shifting cultivation, charcoal making, brick burning, pole and timber harvesting together with population pressure, can influence plant size and architecture (Maass, 1995). Frequent fires destroy vegetation and retard the growth of many plants. Plants tolerant of fire environments like *B. aegyptiaca* tend to survive more easily with thick fire resistant bark and/ or can regenerate by sprouting from root suckers or surviving stems. Possession of specialized below-ground organs like rootstocks or lignotubers that cannot be easily killed is also associated with fire tolerance (Crawley, 1986).

Human beings and browsing animals create a characteristic population having species whose morphology gives them a certain tolerance of bruising, compression and other physical effects. Human impact has a significant influence where species have good commercial wood value. Removal will normally concentrate on large trees of good form, leaving behind those, which are small, or of poor form as the residual population (Errickson et al., 1973). Hence the extent to which different communities are exposed to this pressure may result in sites having populations with contrasting size class and spatial features.

2.3 Fruiting and fruit production potential of woodland Trees Species

Studies of fruiting phenologies in tropical forests are also useful in indicating fluctuations in fruit production of tropical trees in time and space (Terborgh, 1998), and are associated with the availability of pollinators (Okullo *et al*., 2004). The time at which fruits, seeds and vegetative material can be collected for consumption and propagation are highly influenced by the phenology of a species (Simons, 1997). Because the environment influences morphological expression, phenology will be influenced by seasonality. Environment thus plays a role in triggering Phenological changes in tropical woody plants (Khan, 1999). The timing of flowering of a species within a population/community and their spatial distribution invariably thus needs to be known as these may have a big influence on the overall pollination and seed production of the species (Pouakouyou, 2002).

In the dry tropics (Karamoja for this case), the environment is less constant and flowering seems to be seasonal and follow rainy or dry periods (Borchet, 1996). The observation that many plants flower at a particular season or time of the year implies that flowering is influenced and perhaps controlled by changes in the environment (Pouakouyou, 2002). In all habitats, however, variations in the environment provide potential cues for the plant to make use of it. This ensures that the transition to reproductive growth coincides with the conditions most likely to lead to successful completion of flowering, fruiting and seed dispersal (Okullo *et al.,* 2004). Plants may also use environmental signals either to promote flowering, so that a favorable environment for reproductive growth can quickly or successfully be exploited, or to delay it until it can be achieved optimally (Okullo *et al.*, 2004). In this regard, the critical parts of the reproductive process of a plant such as pollination, fertilization, and fruit and seed formation have to be set in, by transition to flowering, several weeks or months before eventual culmination

Generally, the first opportunity environment has in influencing fruit numbers occurs at the time of flower initiation (Drury, 1998) and in response to varying environmental conditions. Therefore, plants may adjust the resources committed to seed production by altering among other traits, the number of flowers that differentiate and the number of fruits or seeds that abort (Okullo *et al.,* 2004). So, the question then arises as to which developing fruits mature and which abort in *B. aegyptiaca?*

In many woody angiosperms, abortion may occur as a result of competition for nutrients supplied by the parent plant or of developmental anomalies induced by genetic or phenotypic physiological deficiencies (Torres & Galetto 1999). This can occur in both cross and self- pollinated flowers. More so, flower or fruit - abortion because of genetic incompatibility may be less important than other mortality factors such as resource limitation (Okullo *et al.*, 2004). This can be tested by hand pollinating the whole inflorescence and correlating the abortion rates with the number of fruits developed before them (Torres & Galetto 1999). Initiation of excess fruits and seeds as from evolutionary point of view may be favoured by several environmental factors for instance unpredictability of the physical environment, pollination quantity and quality, and fruit and seed predation (Okullo *et al.*, 2004). There is also a possibility that selective abortion of fruits and ovules may improve offspring quality (Stephenson & Windsor 1986) and represent an adaptive trait. At the same time, there is a possibility that it is not necessarily adaptive and plants may over initiate fruits simply because selection of individuals has favoured the over initiation in flowers (Lee, 1988).

Production of surplus flowers in most angiosperms appears to be related to selection for increased pollen dispersal as a result of competition for mates and for attracting pollinators (Torres & Galetto 1999). It has been hypothesized that production of excess flowers would be favoured if the increase in male fitness gained through pollen donation by these excess flowers was greater than the loss in female fitness and the loss in female fitness being caused by not allocating those resources to additional fruit maturation (Wilson et al., 1994). This hypothesis attributes large inflorescence size to selection through male function (Burd, 1998). More so, opportunities for male-to-male competition depend fundamentally on the distribution of open grains among flowers, which in turn is dependent on the behaviours of pollinators.

Hermaphrodite plants for example *B. aegyptiaca* may adapt to increase male fitness through pollen donation by nectar production that provides the plants with a non-structural mechanism for dispensing pollen (Richards, 1997). This could be in the form of variability in nectar (flower rewards in many angiosperms) that might be mainly linked with female function or with male function (large nectar availability when the flower opens), variation in nectar production as the plant ages and resumption of secretion after nectar removal (Torres & Galetto 1999).

The physical location of a flower within an inflorescence can again affect its chance of producing a fruit (Torres & Galetto 1999). In the absence of pollen limitation, there are two possibilities to explain flower position effects on a flower's probability to set a ripe fruit. The first is the distance to the parent plant's pool of resources. The second is the time of fruit initiation in relation to other developing fruits competing for a share of limited resources (Torres & Galetto 1999). Even if resources might limit fruit set in some species, when a developing fruit exceeds the size for abortion it will ripen. The ripen fruit would invariably show the same fruit-traits quality, irrespective of its position within the inflorescence (Torres and Galetto 1999).

For several species, a reduction in the level of competition among developing fruits can also be experimentally confirmed by pollinating a fraction of inflorescences or flowers; the result of which could be an increase in the proportion of the flowers that produce mature fruits (Torres & Galetto 1999). However, the pollination processes, particularly when dependent upon the provision of pollinating agents such as honeybees, is both expensive and inefficient (Okullo *et al.,* 2004). The timing and duration of reproduction may differ appreciably among groups of plants with different pollination (or dispersal) vectors (Bullock, 1995). The seasonality of flowers visited by all sizes of bees is markedly different from that of large bee flowers, implying that the mixture of pollination types present may well affect community phenology although analyses comparing sites and habitats by vector type are lacking (Opler, 1983).

2.4 Fruit production determinants

2.4.1 Tree size and Age

A study by Boffa (1995), found a positive correlation between fruit production and diameter of Shea tree over a range of 10-44cm DBH. Stroflberg et al., (2008) reported that diameter of a tree at an advanced stage is usually accompanied by reduced crown growth vigor leading to a decline in photosynthetic rate and eventually fruit production. Muchiri and Chikamai (2003) in their study on Baobab found that fruit counts would be better estimated by DBH than either tree heights or tree crown diameter. Although the length of time from planting to fruit bearing varies with the type of fruit tree, trees that grow at a moderate rate generally bear fruits sooner than those that grow either too quick or too slowly Maghembe (1994).

2.4.2 Biennial bearing

A study by Nikiema and Umali (2007) reported that variation in fruit production of v. paradoxa trees in Burkina Faso on average a production of 15-30 kg of fruits can be obtained per tree rising to 50 kg which could again reduce to as low as 15 kg per tree in two years. According to Okullo et al (2005) local communities in Otuke, Katakwi and Agago have traditionally noted that if a tree yields too much fruits in a given season then the production would relatively lower in the following year.

2.4.3 Human activities

According to Nikiema and Umali (2007) pruning, weeding, application of fertilizer/manure, removing dead and diseased trees can markedly increase fruit production in fruit trees. Leakey et al (2002) documented a fivefold differences in fruit yield of *sclerocarya birrea* trees on farms and on communal lands and attributed this production increase to influence of altered environment and reduced competition. Increase in fruit production in trees can also be due to retention of the better trees on farmlands during bush clearance for agricultural production Shackleton (2004). Human influence like setting early fires have also been reported to be less destructive to the phenological events than fires set late in the season Okullo et al (2005).

2.4.4 Influence of fallow periods

According to Maranz et al (2004), *v. paradoxa* fruit tree appear to perform better in agricultural setting with trees in agroforestry parklands producing more fruits than those in natural settings. Relatedly, fruit production in other wild fruit trees near homesteads and in managed fields is greater than those in from wild tress.

2.5 Carbon Sequestration by woodland Tree Species

The concentration of CO2 and other greenhouse gases (GHGs) in the atmosphere has considerably increased over the last century and is set to rise further. C is accumulating in the atmosphere at a rate of 3.5Pg (Pg = 1015 g or billion tons) per annum, the largest proportion of which resulting from the burning of fossil fuels and the conversion of tropical forest/parklands to agricultural production (Paustian et al., 2000). Scientific evidence suggests that increased atmospheric CO2 could have some positive effects such as improved plant productivity (Keutgen and Chen, 2001).

However, negative changes in the global climate (rising temperatures, higher frequency of droughts and floods) are often the most consequential processes associated with an increased concentration of CO2 in the atmosphere (USDA NRCS, 2000). The debate on the atmospheric buildup of GHGs and their role in global warming culminated in the third session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 1997, in Kyoto, Japan. One of the major achievements of this conference was the signature of a protocol urging participating countries to find ways of reducing GHG concentrations in the atmosphere.

In the case of C, reduction targets could be achieved through two major processes: (1) reducing anthropogenic emissions of CO2; and (2) creating and/or enhancing C sinks in the biosphere. Current terrestrial (plant and soil) C is estimated at 2000±500Pg, which represents 25% of global C, stocks (DOE, 1999). The sink option for CO2 mitigation is based on the assumption that this figure can be significantly increased if various biomes are judiciously managed and/or manipulated. In this connection, agricultural lands have the potential to remove and store between 42 and 90Pg of C from the atmosphere over the next 50–100 years.

According to recent projections, the conversion of parkland area to agricultural land under agroforestry will increase substantially in the near future. Undoubtedly, this will have a great impact on the flux and long-term storage of Carbon in the terrestrial biosphere (Dixon, 1995). Parkland/ or Soil degradation as a result of land-use change has been one of the major causes of C loss and CO2 accumulation in the atmosphere.

Napak woodland, as a dry land forest dominated by IFTs like *B. aegyptiaca* is one of the most important terrestrial biomes contributing immensely to carbon (C) sequestration and storage, and regulating other climate related cycles (Gibbs *et al.*, 2007). There is growing interest in understanding the capacity of forest ecosystems to sequester and store Carbon in developing countries (Walker *et al.*, 2004), which is fundamental in quantifying the contribution of trees to climate mitigation because they indicate the amount of Carbon that can be offset (Ditt *et al.*, 2010).

Quantifying the Carbon under the land use of the woodland will help to make future land use scenarios to ensure optimal land use benefits (Ditt *et al* 2008), hence informing forest conservation and sustainable management (Schongart *et al* 2008) especially in developing countries which have high poverty levels and where peoples' livelihoods depend on the forest resources.

2.6 Indigenous Tree Species Conservation Practices and Strategies

Indigenous fruit trees are characteristic in most vegetation landscapes and serve a dual function of local livelihood support and biodiversity conservation (World Agroforestry Centre, 2008). Among those species in Napak woodland, the desert date tree (*B. aegyptiaca*), a semi-domesticated tree in the zygophyllaceae family is a valuable and multi-purpose indigenous tree in the woodland, hence provides valuable income for farmers who occupy the woodland and those that protect it in crop fields. This traditional agroforestry practice represents an environmentally sound land management system that proved to maintain soil moisture and preserves it from erosion (Traore, 2003).

Following selection and protection, the development of parkland trees such as *B. aegyptiaca*, is aided by traditional silvicultural techniques that include pruning and weeding. Farmers

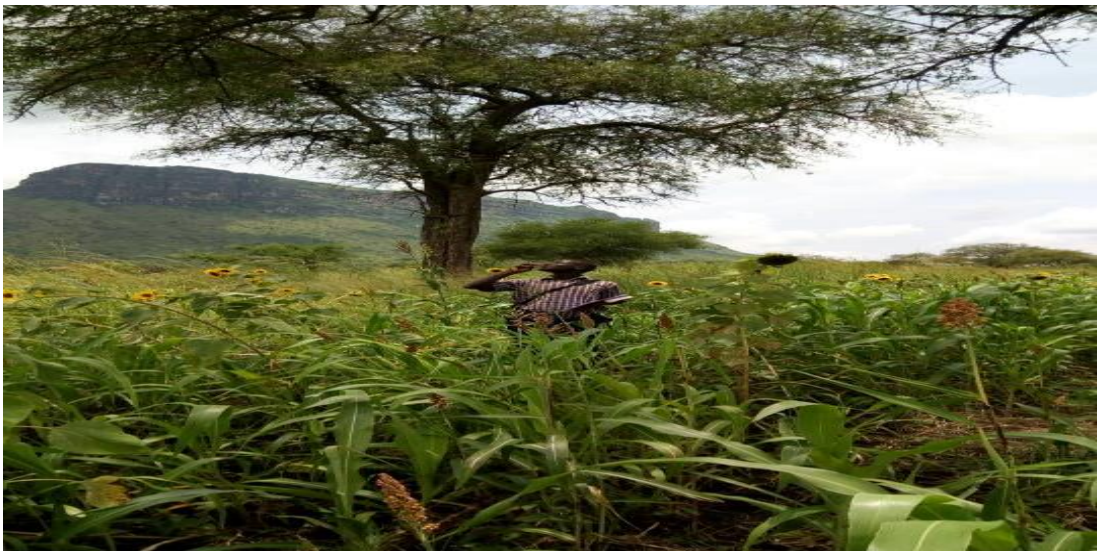


Plate 3: Individuals of B. aegyptiaca intercropped with agricultural crops in one of the plots in Iriiri Parish.

Usually weed around chosen individuals and protect them from fires (Boffa, 1995). In some areas, pruning trees in the farming system generates fuel wood and improves fruit production, reduces crop shading of understorey crops (Bayala, 2002), as well as control of pests However, pruning of *B. aegyptiaca* is rarely done and it is not considered suitable (Hall *et a1.*, 1996) but instead, farmers pollard the lower and middle branches for fuel and as raw material for construction of homesteads (Manyatas) and fencing kraals. Farmers claim that pruning reduces fruit yields (Boffa, 1999) as the potential branches tend to be pollarded from pruning.

However, Desert date trees are intercropped with agricultural crops such as sorghum, yams, maize, millet, cassava, legumes, sesame and cotton alongside a smaller number of other useful trees (Bayala, 2002). The system has been variously called 'bush fallow' where the fields are cleared from woodland leaving only trees of economic importance and the fields are left to fallow at intervals to let the soil regain its fertility (Raison, 1988). This is traditionally practiced in some areas, for example in northern Uganda, as a means of protecting homestead and other valuable trees (Hall *et al.*, 1996).

In most cases, woodland trees have slow growth rates, and long juvenile phases. These have discouraged farmers from planting them and not much has been done to improve them (Byakagaba, 2011). Farmers feel that they will not benefit from planted trees during their lifetime and would rather rely on trees occurring naturally. In addition, because parkland trees are generally wild, fruit/pod production is highly variable from one individual to another; and from year to year.

Unfortunately, increasing demand for firewood, charcoal and poles in these areas leads to severe logging of desert date trees in order to produce charcoal, construction materials and firewood. These activities threaten the species in the woodland and thus reinforce the necessity of understanding factors guiding the species conservation in some particular places (DGFRN, 2010). A study from Djossa *et al.* (2008) previously demonstrated that types of land use affect population structure (termed as the frequency of diameter classes) and spatial distribution patterns of the tropical indigenous trees.

There is much evidence of poor management of ecosystem; the conventional prescription of resource management in many cases does not result in sustainability. In fact, some of the resources crashes of recent years are of greater magnitude than those observed historically. Some others attribute this to short sightedness and greed for utilization and questions whether resources could ever be managed sustainably (Ludwig *et al.,* 1993). Deforestation is one of the major ecological issues in developing countries like Uganda and agricultural land expansion is also its main cause hence hindering sustainability.

CHAPTER THREE

STUDY AREA AND METHODS

3.1 Study area

The study was conducted in Napak woodland. Napak woodland is located in Napak district.

3.1.1 Location and Size

Napak is located in mid-North-Eastern Uganda, and lies between Latitudes 1^0 53'N, 3^0 05N and Longitude 33^0 38'E, 34^0 56'E and elevation of 1454 to 1524m above sea level (GoU, 2013). It shares boarders with five districts of Kotido to the North, Otukei and Abim to the North-west, Katakwi to the west, Moroto to the East and Nakapiripirit to the south. This study was conducted in Napak woodland, in Iriiri parish. All study sites were located on the foot slopes of Mt. Iriiri respectively **(Figure 1).**

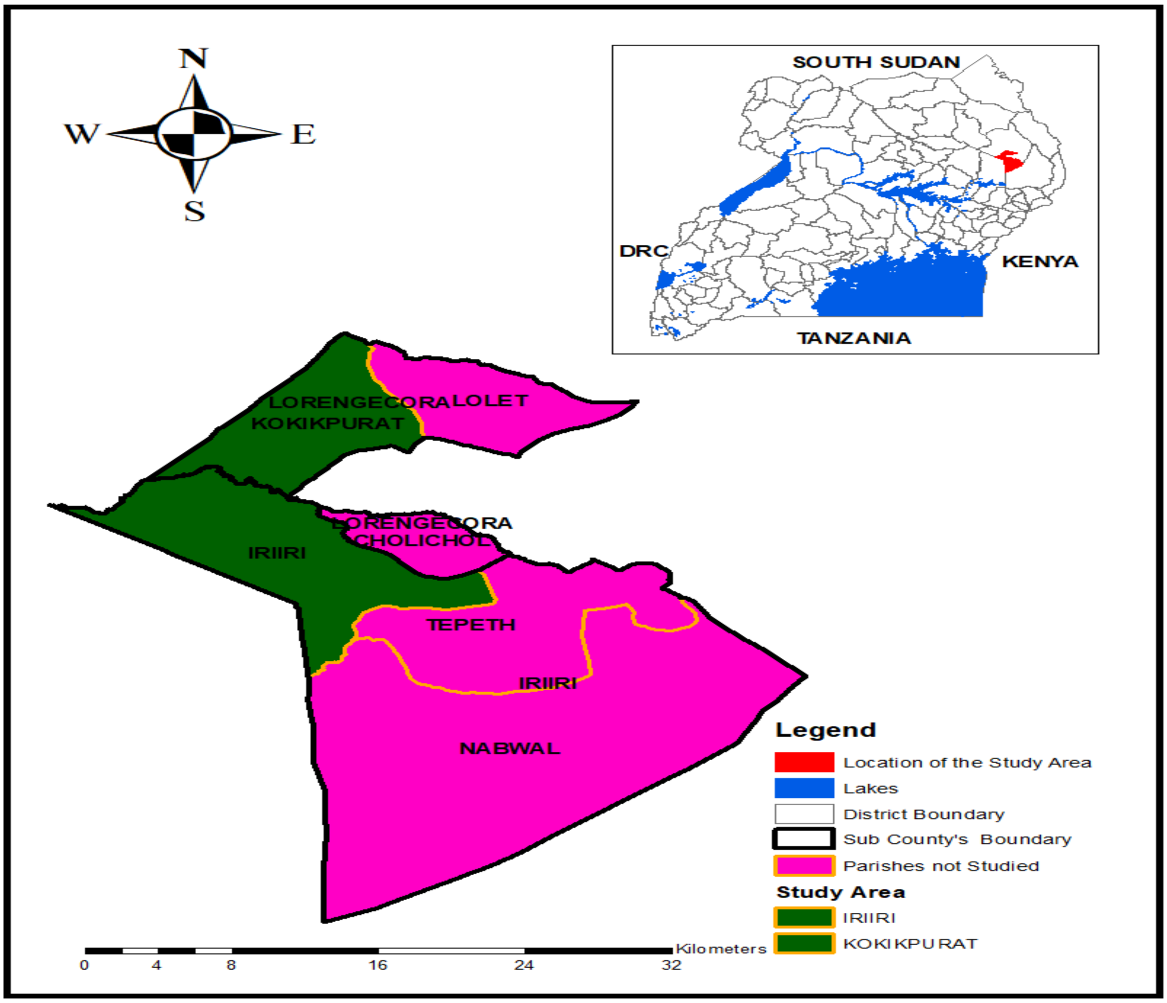


Figure 1: Map of the study area

The sub-county is bordered by Lorengecora, Lopeei, and Lokopo (UNDP, 2014). The study area was chosen due to the intensity of *B. aegyptiaca* in the parkland and the multi-purpose function of the species for which it is used

In the entire Napak woodland, Iriiri sub-county and Lorengecora has the highest number of *B. aegyptiaca. B. aegyptiaca* is the dorminant tree species in the current on-farm sstem (Katende, 2000).

3.1.2 Topography

The topography of Napak district varies greatly within the study area. It consists essentially of plain raising eastwards and northwards to the hilly lands of Moroto. Some of the land in the south-west is below 1000m but most of the district lies above1000m rising from 1,356 to 1,524 meters above sea level (UNDP, 2014). The dominant soils of the study area are ferrasols (UNESCO, 1977) and are mainly undifferentiated acid soils (NEMA, 1997)

3.1.3 Vegetation and Climate

The vegetation pattern in Napak district is typically semiarid with dry savannah tree species and predominantly grass species. The main vegetation communities in the district include forests at high altitudes (dry montane forests), savannah woodland, semi evergreen thickets, deciduous thickets, riparian communities, and grass steppe communities. Forests are localized groves on hills and mountains such as Kamalinga Forest on Mt Napak and Mt. Iriiri in Iriiri. Forest cover is estimated to be not more than 150 km^2 (Local government Planning Unit, 2013).

Napak has a semi-arid climate characterized by intense hot seasons, lasting from November to March (Egweru *et al.*, 2014b). The rainy season runs from April to August with temperatures ranging from 28^0 to 33^0 C during the dry seasons and 15-17^0 C in the wet seasons (UNDP, 2014). The hot periods are also characterized by extensive fires all over the district with smoky haze rising to about 3000M above sea level (GoU, 2003). The wet seasons are marked minima in June and marked maxima in May and July. The rainfall ranges from 300 to 1200mm per year with mean annual rainfall of 800mm (UNDP, 2014).

3.1.4 Population and Communication

The population in the area is 142,224 people, of which 65,518 people are male and 76,706 are females (UBOS, 2017). The main Language in Napak is Ng'akarimojong, Itesot, Kiswahili and English. The road length totals to 254 km which is marram with no all-weather roads. The district has only one air strip located in Matanyi. Settlement in the district is only in sparse, productive agricultural areas, on foot slopes of Mt. Napak and Mt. Iriiri (District Planning Unit, 2012).

3.1.5 Land use and Anthropogenic activities in Napak woodland

Wooded grassland is one of the most widely spread land use systems in northern and Northeastern Uganda. In these woodlands, systems of cultivation of food and livestock stock keeping are constantly changing. There is now overwhelming expansion of agricultural land and more intensive use of areas under agriculture. Even then, the northern and eastern parts of Uganda are presently ecologically fragile, with limited ability to withstand periodic droughts and suffer severely from insurgency and overgrazing (NEMA, 2000).

Several other tree species in Napak woodland in particular, that occur together with Desert date (in Napak woodland in particular), are all exploited, particularly for firewood, building poles, charcoal, timber and crafts. This implies that the structure of the parklands and the distribution and pattern of the tree populations that characterize them are significantly related or as a result of human influences (Byakagaba 2011).

While parklands close to settlements tend to have low tree densities (Plate 2), those on more fertile soils, usually found on lower slopes or in valleys have remained for many years under cultivation, and has resulted into well-developed parklands (Kessler & Boni, 1991).

3.2 Methods

3.2.1 Research Design

This research was a mixed method design (MMD) involving both a house hold survey and on-farm tree inventory. This was designed to collect both qualitative and quantitative data about parkland tree productivity and management (Okullo et al,.2007)

3.2.2 Sampling Procedure

The sampling technique used was purposive sampling (Creswell, 1998). Three different major land use activities were identified for the woodland (1) current farm fields, (2) fallow land, (3) settlement.

To achieve the objectives for this study, fallow land and current fields (covered with annual crops during the time of the study) were encountered and within the land regimes, sample plots each of 100x150 M were established using a systematic random sampling along the transect (Chazdon et al., 2005). The first plot was randomly located (Johnson and Bhaacharyya, 2001) while subsequent plots were established alternatively at a distance of 100 m apart with a kilometer spacing among transects. This allowed the plots to be considered as individual sampling units (Sanau et al., 2006).

A sample size of six (6) key informants were purposively selected and interviewed based on the interview guide so as to obtain qualitative information on the farmers local knowledge and management practices for B. a*egyptiaca* in the parkland.

3.2.3 Plot Establishment

Ground inventories were done in the identified study sites. Four 100m x 150m plots (1.5 ha) were established alternatively along transect 1 in a fallow land and other three transects established running across the mountain slope from the main road extending to the gentle slopes of the mountain which was on current farm field. Sixteen plots of 100mx150m (1.5 ha) were established alternating along transects with a 100m spacing from each plot and at a distance of 1 kilometer apart between transects to avoid overlapping. On a per Hectare basis, transect 1 had a total of 6ha, transect 2 had 7.5 ha, transect 3 had 7.5 ha and transect 4 had 4.5 ha (Kalaba *et al* 2013).

The kilometer spacing between transects was necessary so as to accomplish the challenges in different characteristics for the land use categories. To cater for the occurrence of pre-abandonment land use, maximum emphasis was put on current farm fields and fallow land (Kalaba *et al.,* 2013).

3.2.4 Data Collection

a) Tree Inventory

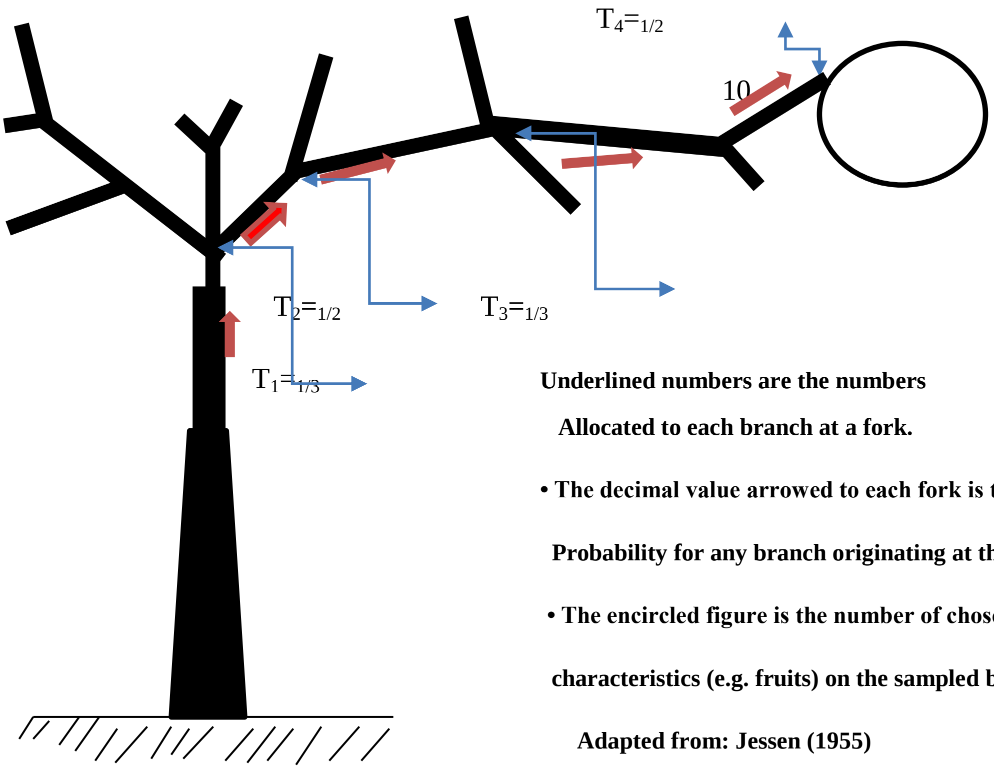
In the established plots along transects, tree diameters were measured using Dbh caliper at breast height for individuals below 50 cm and diameter tape for tree crown diameter and diameter for individuals whose Dbh of 50 cm (1.3m above the ground) (Malimbwi *et al.,* 1994, Ditt *et al.,* 2010). These apply to all trees (considered as woody plants more than 2m (Frost, 1996). Tree forking below 1.3m were measured and recorded separately, while those forking above 1.3m were measured at breast height with the help of a local botanist from Nabuin Zonal Agricultural Research and Development Institute. A total of 240 stems were recorded within the sampled plots.

b) Yield Assessment in *Balanites aegyptiaca*

Fruiting productivity in *Balanites aegyptiaca* was determined by counting the number of fruits (at fruit set) on marked desert date tree in different sample plots and a non-destructive method of Randomized Branching Sampling (RBS) technique was adopted for estimating the number of fruits on marked desert date tree. Figure 2 illustrates a non-destructive method of Randomised Branch Sampling (RBS) technique that was adopted for estimating number of fruits on desert date trees (Okullo, 2004).

Randomized Branch Sampling is a multi-stage probability sampling used to identify a path in a tree such that those resultant segments of the path constitute a probability sample of an entire branch. For example, as shown in the illustration **(Figure 2)** with the resultant probabilities shown as T_1= 1/3, T_2= ½, T_3= 1/3, T_4= 1/2.

In figure 2, supposing that the branching pattern is as shown in figure 2, the estimated number of counted or measured characteristics from each sampled branch is determined by first identifying a path and then recording the selection probabilities of each branch at a forking.



Underlined numbers are the numbers Allocated to each branch at a fork.

- **The decimal value arrowed to each fork is the Probability for any branch originating at that fork.**
- **The encircled figure is the number of chosen characteristics (e.g. fruits) on the sampled branch.**

Adapted from: Jessen (1955)

***Figure 2*: Branching systems of a tree and the selected probability at each fork, as adapted from (Jessen 1955)**

In Figure 2, there are four selection probabilities at four forks, (T_1 x T_3 x T_3 xT_4). If the branch had 10 fruits as it can be seen in the above figure, the initial estimation of fruit number from the branch will be:

$$\text{Fruit Estimate} = \frac{\sum \text{number counted on the sampled branch}}{\text{Product of selection probability at each fork in the path}}$$

$$= \frac{10}{\left(\text{T1}=\frac{1}{3}\right) \times \left(\text{T2}=\frac{1}{2}\right) \times \left(\text{T3}=\frac{1}{3}\right) \times \left(\text{T4}=\frac{1}{2}\right)}$$

$$= \frac{10}{\frac{1}{3}\text{x}\frac{1}{2}\text{x}\frac{1}{3}\text{x}\frac{1}{2}}$$

$$= \frac{10}{\left(\frac{1}{36}\right)}$$

$$= 360 \text{ fruits}$$

Branch from a fruit bearing tree was selected and tagged for easy monitoring (Okullo, 2004). Unbiased estimate of the total number of fruits was determined at fruit set by counting and recording the number of fruits. For such a case study, one branch is most times sampled as a probability for the rest and then estimate for each tree is multiplied by the total number of branches from each tree. Depending on the number of branches on the tree and its characteristics, tree branches would be stratified into lower, middle and upper canopies to determine the effect of canopy strata on fruit production (Jessen, 1955).

In this study four (4) branches/paths were sampled per tree, to cater for the large canopies of *B. aegyptiaca*. The estimates for the paths sampled in the crown were then averaged to provide a pooled estimate for the particular tree. It is always necessary to adjust the estimates for each path because the values are affected by the selection probabilities and the numbers of forks involved (Okullo, 2004).

To attach more confidence to the final estimated total, branch estimates with higher cumulative selection probabilities are given more weight. This is achieved by weighting the estimates of the tree's fruit crop from each sampled branch in proportion to the cumulative selection probability. The revision of the estimated number of fruits is obtained by weighting the initial estimates and summing the weighted values (Jessen, 1995)

c) Carbon Sequestration

Above Ground Carbon (AGC) was determined by first lying four transects in two different land use sites in Iriiri parish with transect 1 laid in a fallow land and the rest in current farm fields. Plots were set alternatively along the transect to cater for the different size classes of ≥5cm and above owing to this Dbh ranges so as to avoid errors in biomass estimates (Chave *et al*., 2004). The size class interest of the study ranged from ≥5cm to <50cm. For the case of this study, the technique and the allometric equation used for estimating the above ground carbon was adopted from (Brown *et al.*, 1998). The Allometric equation is the one developed for dry tropics like Napak woodlands. (Table 3)

Table 1: Biomass Allometric equations

Reference	**Equation**	**Source country**	**Notes**
Brown *et al* (1989)	$B=34.47-8.067D+0.659D^2$	Dry tropics	Developed in dry tropics and therefore not Miombo specific

Where***: B is Biomass; D is the diameter at breast height***.

d) Key Informant Interviews

Interviews were conducted with key informants stratified into local council one (LC1), Women representative, Youth representative, elder representative, Traders representative and a collector of the tree resources with specialized knowledge about the tree species. Respondents were asked to provide information on a wide range of issues regarding *B. aegyptiaca* such as its management, production and utilization and its products. Key informants discussions based on interview guide explored and probed key aspects related to management, conservation and utilization of *B. aegyptiaca* (Okia, 2011). Additional information captured included constraints as well as opportunities for improved use and management of *B. aegyptiaca* in the study area. A total of six (6) key informant interviews were conducted.

c) Review of Secondary Information

Relevant secondary information on the study area, location and size, vegetation, economic activities, information on the desert date tree were gathered from Makerere University main library, School of Forestry, Environmental and geographical sciences and other publications.

3.2.5 Data Analysis

a) Tree inventory (Density distribution)

Data on tree inventory were analyzed in Excel XP for diameter distribution, size classes, population density, and tree size classes. Within populations and combined populations, trees were referred to the appropriate dbh classes (10-19 cm, 20-29cm, 30-39 cm, 40-49 cm, 50-59 cm, 60-69 cm, 70 cm or more) and crown diameter 1.7m, 4.4 m, 8.5,11.4 m, 11.5m14.4 m, 14.5 m or more); (Okullo, 2004).

b) Yield assessment (Fruiting potential)

Data on yield assessments were entered in MS excel and computed as the total number of fruits at fruit set for each tree crown inventoried (Azher Nawaz *et al*., 2008).

One-way ANOVA was used to examine variations in the mean of fruit set for each tree assessed in all plots. Means were separated using one-way ANOVA to get LSD for different parameters. Pearson's correlation was used to determine the relationship between tree characteristics and fruit production (Sokal and Rohlf, 1995)

c) Quantifying Above Ground Carbon

Data from inventoried tree were entered in MS excel and for the combined population, trees were categorized and subjected to Allometric equation $\mathbf{B=34.47-8.067D+0.659D^2}$ to estimate tree biomass (Brown *et al* 1989). This equation is applicable to the study area owing to the climatic, edaphic, geographical and taxonomic similarities between the study area and the location in which the equation was developed. The Allometric formula was objectively designed for the dry tropics like Miombo and Karamoja regions.

According to a study by Brown *et al* (1989), local equations are more suitable for accessing forest biomass. This study objectively restricted the biomass estimates to trees with DBH ≥ 5. This helped to avoid errors in the biomass estimates (Chave *et al* 2004). Carbon stock in the plots was calculated by multiplying biomass by **0.5** owing to the fact that 50% of biomass is carbon (Bryan *et al.,* 2010).

B

CHAPTER FOUR

RESULTS

4. Characterization and population structures of *Balanites aegyptiaca*

4.1. Size class distribution/ vegetation structure.

4.1.1 Number of trees per hectare

B. aegyptiaca tree density ranged from as little as 39 individuals per hectare to as many as 92 individuals per hectare in Iriiri parish. The summary of density of *B. aegyptiaca* trees by dbh category are presented in **(Table 2)**

Table 2*:* Summary of inventoried Balanites aegyptiaca trees density by Dbh category in all populations – Iriiri Parish, Napak district-north-eastern Uganda

DBH Class (cm)	Iriiri parish Trans 1 (6 ha)	Iriiri parish Trans 2 (7.5 ha)	Iriiri parish Trans 3 (7.5 ha)	Iriiri parish Trans 4 (4.5 ha)	Average No Trees/ha
<10	1.0	0.0	0.0	0.0	1.0
10-19	9.0	2.0	0.0	2.0	3.0
20-29	13.0	13.0	25.0	7.0	15.0
30-39	14.0	20.0	20.0	11.0	16.0
40-49	2.0	41.0	23.0	15.0	20.0
50+	0.0	16.0	6.0	35.0	14.0
Total	39	92	74	70	69

(Tran1= Transect one, Tran 2= Transect two, Tran 3= Transect three, Tran 4= Transect four)

The highest tree density was in the 20-50 cm diameter classes for all transects. There were no trees beyond 50cm dbh in transecting 1 and no individuals in the dbh category below 10 cm for transect 2-4 in the study area (Table 2).

4.1.2. Size class distribution

The stocking density in all population was dominated by middle diameter classes ≥20 to ≤50cm with very few at lower ≤20 cm and upper (50+) density diameter classes **(Figure 3).**

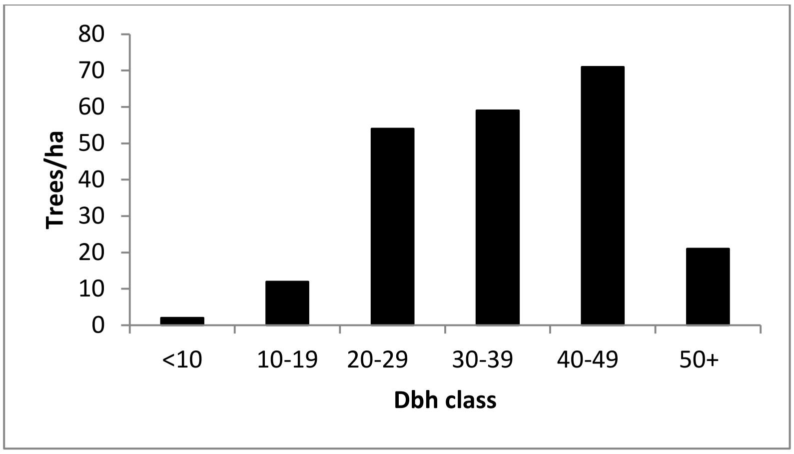


Figure 3: Diameter size class distribution of B. aegyptiaca trees in Iriiri parish

The stocking density for all the populations increased with increase in dbh size classes. Diameter classes of 5-20cm and 50+ occupied the lowest peak of the figure and diameter classes 20-50cm occupied the highest peak of the figure hence indicating a bell shaped distribution of individual in the population.

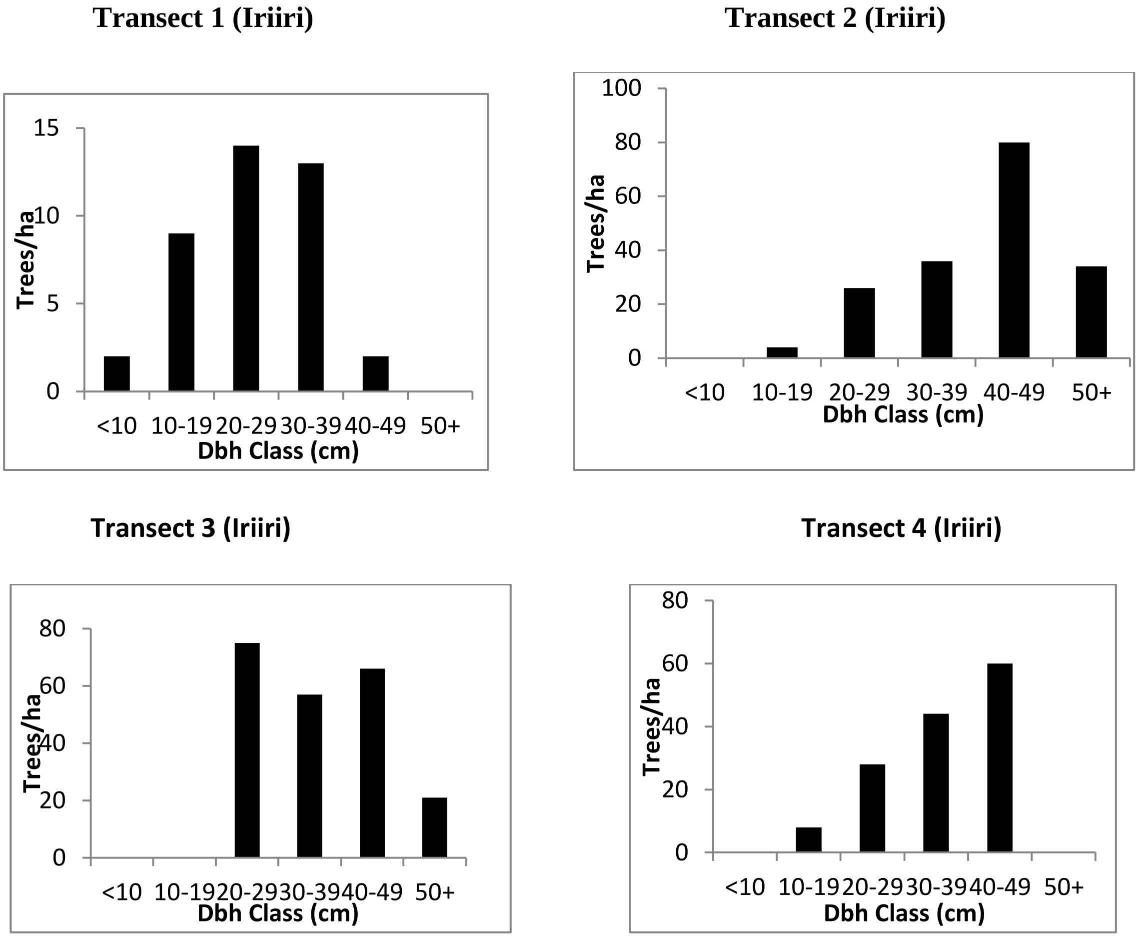
Significant differences (P< 0.005) were noted in the mean Dbh among the different size classes in the populations (**Table 5**).

Table 3: Analysis of variance for the populations mean diameter at breast height

Source	DF	SS	MS	F	P
Transect	3	15279	5093	28.71	0.000
Error	252	67583	177		
Total	255	82863			

4.1.3 Diameter frequency of sampled Desert date trees

Balanites aegyptiaca tree size class (density dbh) distribution in each population is represented in **Figure 4**


Transect 1 (Iriiri)

Transect 2 (Iriiri)

Transect 3 (Iriiri)

Transect 4 (Iriiri)

Figure 4: Diameter class distribution of Balanites aegyptiaca in each of the four transects in Napak woodland. Napak district

The populations consisted of the majority of middle to large diameter individuals (≥20 – ≤50 cm) in transects 2 to 4, with few smaller individuals at ≤20 cm. Transect 1 had more individuals in smaller dbh size class (≤20 cm) and very few larger dbh size classes (≤40 cm).

Combined for all populations, the size classes of the 240 trees showed a normal distribution pattern in transect one, a left skewed pattern in transect 2 and 4 and a right skewed pattern in transect 3 (Figure 4).

On a per hectare (ha) basis, the Dbh categories ≤10 had about 1 individual tree/ha, 10.1-20 and at least 3 trees/ha, 20.1-29 cm had about 15 trees/ha, 30.1-40 had 16 trees/ha, 40.1-50 had 20 trees/ha and >50 cm had at least 14 trees/ha.

4.1.4 *B. aegyptiaca* Crown diameter and canopy cover distribution

Crown diameter distribution of *B. aegyptiaca* by Dbh, is presented in (**Table 4).**

Table 4: Descriptive Statistics for crown diameter

DBH (cm)	Total Trees Sampled	Minimum	Mean±SE	Maximum	StDev	Var
10-19	13	0.6	2.0±0.69	4.2	0.924	0.853
20-29	58	0.8	3.3±3.08	6.3	1.155	1.334
30-39	65	2	4.3±9.69	8.2	1.335	1.783
40-49	81	2.3	5.0±7.29	8.7	1.244	1.549
50+	22	4.4	7.1±7.40	14.1	1.360	1.850

Trees of dbh >50 had the widest crown diameters, of 4.4 and 14.1m. The smallest crown diameters were witnessed in dbh classes of ≤30cm with a diameter range of 0.6 as the minimum and 8.2 m as the maximum crown diameter. For all populations, the highest mean crown diameter was in the Dbh category greater than 50 cm (7.1±7.40 m) and the lowest crown diameter (2.0±0.69m) was in the Dbh category of 10-19 cm **(Table 4)**.

Crown diameter differed significantly among populations (P= 0.000) with average mean crown width ranging from 0.6 to 14.1m. The crown diameter mean± SE ranged from 2.0 ± 0.69 m to 7.1±7.40m.

Table 5: Anova for crown width and Dbh

Source	DF	SS	MS	F	P
Dbh	188	1180.48	6.28	2.19	0.001
Error	49	140+61	2.87		
Total	237	1321+09			

4.2. Fruiting Potential of *Balanites aegyptiaca*

4.2.1 Fruit production

The sampled reproductive *B. aegyptiaca* trees varied from 7 to 120+ cm in dbh, and from 0.6 m to 14.1 m in crown mean diameter. All trees sampled were of bearing age. There was much variation in individual branching patterns. The number of reproductive/flowering branch units per tree ranged from 2 to 108; giving a mean number of reproductive branches as 3310.0±312.5.

Descriptive statistics for fruit production are presented in (**Table 6)**.

Table 6: Fruit production (fruit set) by DBH category

DBH (cm)	**No of Tree Sampled**	**Minimum**	**Mean±SE**	**Maximum**	**StDev**	**Covar**
10-19	13	18	273±861.0	926	311.50	97052.9
20-29	54	12	886±203.4	3982	856.28	733224.5
30-39	52	37	669±153.2	6408	1,480.87	92991.1
40-49	63	428	2,472±111.1	12,288	2,337.22	5462600.1
50+	16	1,158	3310.0±312.5	6,994	1,743.96	3041426.3

Estimates of numbers of fruits at onset derived from the randomized branch sampling are positively skewed.

The highest fruit set was observed in the Dbh category (40-50) cm with a mean fruit production of (2,472±111) fruits, followed by the Dbh category of 50+ cm with a mean fruit production of (3310±312.5) fruits while the lowest fruit set was observed within the category of 10-19 cm with a mean fruit production of (273±861).

The most productive desert date trees seem to be in the dbh range greater than 25 cm but less than 70 cm *(i.e.* ≥25 cm to ≤75 cm). The fruit production is likely to decline above a dbh of approximately 80 cm. The desert date trees in this range (>30 to 60 cm) contributed most to the total fruit yield and also produced well during the period.

ANOVA revealed a high significant difference (P=0.004) in fruit set within the Dbh classes (**Table 7**).

Table 7: Anova of Total Branch Number and total fruits on crown

Source	DF	SS	MS	F	P
Total fruit on C	197	105305	575	3.61	0.004
Error	40	2231	159		
Total	237	107536			

Regressively tested Allometric relationships between fruiting intensities/yields (estimated by randomized branch sampling method) at onset stages respectively revealed that morphological parameters such as crown diameter (CD) and number of fruits at fruit onset act together in influencing on fruit production in Desert date.

Fruit yields of Desert date were found to vary greatly with crown size and Dbh. Average fruit yield, crown and tree diameter at breast height were significantly correlated

(P=0.000) **(Table 8)**.

Table 8: Analysis of variance for total fruit on crown versus Dbh

Source	DF	SS	MS	F	P
Total fruit on C	197	34154.9	186.6	5.44	0.000
Error	40	480+0	34.3		
Total	237	34634+8			

The most productive desert date trees seem to be in the dbh range greater than 25 cm but less than 70 cm (i.e. ≥25 cm to ≤75 cm). The fruit production is likely to decline above a dbh of approximately 80 cm. The desert date trees in this range (>30 to 60 cm) contributed most to the total fruit yield and also produced well during the period.

Correlation analysis between fruiting potential, Dbh and crown width revealed that was strong in all transects with significant differences at P=0.000. There was a correlation between crown width and Dbh which was quiet strong (**Table 9**).

Table 9: Correlation relationship between Total fruit, Dbh, Fork No and crown width

Parameter	*Total fruit*	*DBH*	*Total branch*	*Crown width*
Total fruit	1			
Dbh	0.345 (0.000)	1		
Total branch	0.367 (0.000)	0.658 (**) (0.000)	1	
Crown width	0.341 (0.000)	0.731(**) (0.000)	0.219 (0.001)	1

***** Correlations Significant at 0.01   Bracket values represent r-values***

4.3. Ability of *Balanites aegyptiaca* to Sequester Carbon

4.3.1 Above Ground Carbon

The estimated minimum and maximum Above Ground Carbon was 5.15 and 2940 Mg C ha^{-1} per tree with mean of 5±22 Mg C ha $^{-1}$ and 1168±87 Mg C ha^{-1} per tree **(Table 12)**. Results from the study showed that more carbon was sunk in plots with individuals of Dbh >30cm as observed in (**Table 10)**.

Table 10: Descriptive Statistics for Above Ground Carbon sequestered in all Transect

Dbh (cm)	**Trees sampled**	**Minimum (Mg C ha^{-1})**	**AGC Mean±SD**	**Maximum (Mg C ha^{-1})**	**SE**	**Var**

<10	01	5.15	5.22±0.09	5.28	19.20	0.01
10-19	13	20.49	63.16±66.8	281.61	48.11	4463.95
20-29	58	70.21	121.02±36.5	191.21	37.54	1335.11
30-39	65	192.78	278.94±50.0	369.82	38.71	2504.39
40-49	81	374.22	497.47±75.8	633.54	94.90	5745.24
50+	22	639.31	1168.87±694.6	2939.9	125.6	482565.69

Trees in the Dbh class of ≤10cm sunk least carbon with a mean of 5.22±0.09 and 2939.9 Mg C ha^{-1} as the minimum and maximum amounts. The carbon sequestration rate was highest in the middle and upper Dbh size classes of >20-50cm and 50+ Dbh. The sequestration rate varied among the populations. *B. aegyptiaca* tree with dbh range of ≥30 sunk statistically higher C than trees with dbh ranges of <30cm. Statistical differences in C sequestration was also observed in the middle and higher dbh ranges with no much significant differences among individuals in the study site (**Table 11**).

Table 11: ANOVA of Carbon sequestered versus Dbh

Source	DF	SS	MS	F	P
Dbh	48	30848714	642682	18394.33	0.000
Error	189	6603	35		
Total	237	30855318			

A one way ANOVA showed that there were significant differences (F= 18394.33, P-Value = 0.000) in sequestered carbon estimates among the Napak woodland stands (**Table 11**).

4.4. Conservation practices carried out by local farmers in the study area

4.4.1 Conservation and management practices for *B. aegyptiaca*

Key informant and focus group discussions were held with communities in three villages during the study. From these discussions, the major land uses were settlement, charcoal burning, animal rearing and staggering crop growing. High flowering and fruiting potential was reported to be associated with onset of rains, enough light for flowering, pruning and high temperature. Bush burning/ wild fires and prolonged drought were reported as the major causes of premature flower and fruit drop in desert date.

No specific management practices were being applied to conserve desert date trees apart from those spotted and singled in crop fields and those trees located in sacred places (**Table 12)**.

Table 12: Summary of Key informant interview Reported on management practices being applied to B. aegyptiaca in Iriiri parish

Category	**Land uses**	**Factors for flowering and fruiting**	**Factors for premature flower and fruit drop**	**Farmers local knowledge on conservation**	**Status and rate of use**	**Uses of the tree**	**Measures for continued conservation**
Farmers (Nabwal) and (Kolochelel**)**	Bush burning, settlement, animal rearing, charcoal burning	Rainfall, pruning, light, high temperatures	Bush burning, prolonged drought, overgrazing	agro-forestry, pruning for trees in crop fields,	Trees are disappearing/ more preferred for charcoal, fuel wood and raw materials	charcoal, construction poles, firewood and fruits	Educate communities on the importance of desert tree
Youths (Nabwal)	Crop growing, animal rearing, charcoal burning, settlement	Rain, conserving in crop fields, stop cutting trees, awareness on value of tree	Wild fires	No conservation practices apart from those in crop fields	Trees are disappearing/ a target for use as firewood, charcoal.	For charcoal, construction poles, firewood and fruits	Educate communities on the importance of the tree and disadvantages of cutting them.
Chairpersons	Crop growing, animal rearing, settlement	Rainfall, agroforestry, lack of bush burning, long duration of rains	Bush burning, onset of dry season	No conservation practices only for those in crop fields	Trees are disappearing/ no Authority in place	For charcoal, construction poles, firewood and fruits	Educate communities on the importance of desert date tree and disadvantages of cutting them, promote agroforestry.
councillors	Animal rearing, crop growing, settlement, charcoal burning	Rain, high temperature, low rainfall, light	Bush burning, prolonged drought, deforestation.	Pruning for only those in crop fields	trees are disappearing/ no authority in place	For charcoal, construction poles, firewood and fruits	Educate communities on the importance of desert date tree and disadvantages of cutting them.
Student (in school)	Settlement, farming, animal rearing, bush burning	Rainfall, sunshine	Too much wind, presence of other trees.	No conservation practices	Trees are disappearing	For charcoal, construction poles, firewood and fruits	Creation of awareness by government and NGos.

Generally, *B. aegyptiaca* trees were reported to be endangered due to it being preferred for charcoal production, firewood, construction poles and fruits. The fruits of *B. aegyptiaca* were reported to be utilized due to its preference for food and herbal medicine for (curing stomach disorders).

CHAPTER FIVE

DISCUSSION

5.1. *B. aegyptiaca* population structures and stands management

The size class distribution of *B. aegyptiaca* is diagrammatically shown in Figures 3 and 4. The structure is characteristic of populations that experience sporadic or irregular size class distributions. The actual level of regeneration may be sufficient to maintain the population, but its infrequency of occurrence causes notable ‘peaks’ and ‘valleys’ in the size class distribution as new seedlings grow into larger size classes (Okia, 2005).

From the figures, there is a sharp increase in middle size classes but smaller and larger diameter classes are very few and absent in some plots. This type of distribution is common among late secondary species that depend on canopy gaps for regeneration (Peters, 1994). It also reflects a population whose regeneration has been temporarily interrupted through excessive harvesting of desert date products, direct physical damage to seedlings or adults such as trampling by desert date collectors and grazing livestock or lack of pollinators or dispersal agents (Okia, 2005).

Many studies have also documented decrease in the tree density with increase in diameter class including Krishnamurthy (2010) in kamataka; Sahu *et al* (2012) in Eastern Ghats and Gupta joshi (2012) in western Bengal. In this study, size class distribution of *B. aegyptiaca* seems to have been interrupted with very few, negligible or nil density from (5-20) cm diameters and beyond (50) cm in the plots inventoried. The interrupted distribution of individuals in different growth phases is an indicator of unhealthy growth (Cheoby and Sharna, 2013).

Such interruptions could be attributed to cattle rustling from the 1980's to date which has resulted into loss of household capital in whole of Karamoja sub-region. In this sub-region, many B. aegyptiaca trees are being cut for charcoal production, timber and tool handles (Okullo *et al*, 2004). Fire incidences have also increased; intensifying threats to regenerating B. aegyptiaca tree individuals (Okia, 2005). Other threats to the population of *B. aegyptiaca* are the activities of farmers and local community as well (Okullo *et al.*, 2004).

The farmers and the local community influences have been more on larger diameter class (>20-50) cm in the sampled plots. The densities of mature trees (middle to large size classes) are relatively high and almost similar in all populations (**Figure 4).** Other parkland studies elsewhere by Odebiyi et al., (2004), Djossa et al., (2008) indicate that densities of mature woodland trees such as *V. paradoxa* trees are high in current fields than other land uses. The insignificant variations in mature *B. aegyptiaca* trees in this study may have been due to the fact that within the woodland, (especially where there are traditional conservation regulations) all productive *B. aegyptiaca* trees irrespective of the land use type are preserved (Lovett and Haq, 2000). This therefore, implies that mature desert date tree densities are bound to be more or less similar in areas where they are considered important despite the existence of the different land uses.

In Napak woodland, *B. aegyptiaca* trees existed with fruits and in varying intensities than expected dimensions. The notable ones were witnessed on trees in Transect one with high young leaves and shoot development and transects 2-4 with moderately old leaves but less shoot development. The differences witnessed could be due to fires and pollarding as observed in the different plots during the study and also the ranges in topography (Kalaba *et al* 2013)

The variations in *B. aegyptiaca* crown cover just like other woodland trees do mainly reflect variations in nature and intensity of human activities (Breman and Kessler, 1995). As trans human processes becomes more and more permanent, tree parklands are transformed into agricultural fields which are characterized by trees spaced in a more regularly dispersed configuration. For the case of *B. aegyptiaca,* local communities and farmers in this region expect to harvest abundant tree resources from already mature trees rather than to plant and wait for trees to reach maturity (Okullo *et al.*, 2004). In fact, the communities in this region prefer short term gains from the woodland tress specifically desert date trees than longer term ones, hence, forcing the farmers to protect the older trees forgetting that mature *B. aegyptiaca* individuals need replacements in the long run (Byakagaba, 2011). As clearly seen from **Table 2** and **Figure 4**, there are no or very few *B. aegyptiaca* individuals in sapling or poles of Dbh (≤ 20 cm) entering the reproductive phase.

The extremely low sapling densities of *B. aegyptiaca* witnessed in this study confirms studies done elsewhere by Lovett (2000), where farmers were found to be only interested in mature productive V. paradoxa trees and therefore, cut down saplings that interfered with their crop production. The low densities of various size classes of *B. aegyptiaca* in all study sites suggests that land owners may not be aware of the values of young individuals in sustaining *B. aegyptiaca* population. This may not immediately have a negative impact on the current adult population but will certainly in the long run be noticeable when the adult desert date trees reach senesce due to lack of regenerating individuals that can replace adults in a few years unless the issue is urgently addressed (Byakagaba, 2011).

When farmers become conscious about woodland trees and their products as having increased economic demand, more protection and reproduction of the parkland trees is likely (Boffa, 1999). In most cases, however, some farmers in this woodland have and are trying to neglect the desert date tree resources for other alternative practices or income earning activities that can yield higher immediate benefits than parkland trees. A case in point is opening up more land for the cultivation of field crops like sunflower, sesame and cassava crops that take only few months to grow so as to yield cash income within few months (Okullo *et al.*, 2004). **(Plate 4)**

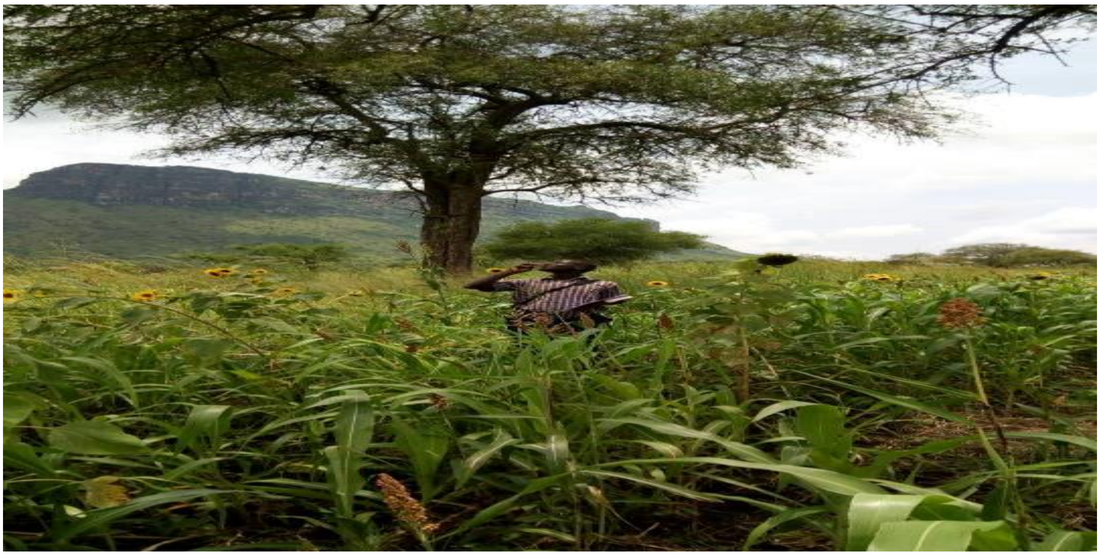


Plate 4***: Individuals of B. aegyptiaca intercropped with agricultural crops in one of the plots***

This process is already evident in Napak woodland (Iriiri) with escalated effects like food insecurity and external pressures from high fuel wood demand in neighboring towns, urban centers and schools.

In most transects and plots, there is clear evidence of lower and middle size class *B. aegyptiaca* trees being cut at a high rate for production of charcoal and construction material (Plate 2). Such high rate of tree cutting seems to be responding to changes relative to the prices offered for a bag of charcoal and inadequate mature ones of other indigenous tree species in the study areas where displaced community members usually return to harvest poles for construction of Manyatas.

Most existing regenerating *B. aegyptiaca* individuals in Napak woodland are naturally regenerating ones although it is somehow uncommon to find desert date regenerating on fallow lands under mature trees soon after the rains, during or immediately after fruit harvesting time. Apart from natural regeneration being very slow, growth rates regenerated seedlings are uneven and the regenerating seedlings are rarely recruited into the sapling stage due to destruction by fires, browsing animals and removal during cultivation for agriculture (Okia, 2005).

Several other factors could also be extensively contributing to this situation. Just like in other woodlands, the present destruction of native forest by processes like urbanization in Lorengecora and Iriiri trading centers, opening land for agriculture, charcoal burning, crafts, rampant burning, overgrazing, insecurity, population increase and land grabbing, are some of the major conservation problems in the woodland (Okia, 2005). These factors have compromised the future of the traditional management and widespread existence of *B. aegyptiaca* populations in Napak woodland. Habitat transformation and fragmentation have also been considered as part of the main contributing factor in addition to rampant colonization of the woodland by exotic trees such as Eucalyptus and pine species.

Although, the effect of the reported threats to the *B. aegyptiaca* populations may be readily detected, the farmers and local communities of the woodland environment need to be sensitized and collaboratively work together with professional expertise through local international NGOs or government departments. The shared aim must be to enhance the level of natural regeneration, and implement a deliberate programme to assist young trees (wildings) to thrive and mature; replacing old ones which will decline in productivity in the long run (Okullo *et al.*, 2004).

5.2 Fruiting and fruit production of *B. aegyptiaca*

Woodland trees like *B. aegyptiaca* have a great potential of being managed just like any other exotic or tropical fruit trees in Africa, much as their domestications are generally uncommon in African parkland areas. Although, there are a few examples of places where efforts are being made to emphasize and popularize indigenous fruit planting, (for example in the miombo Eco zone), early fruiting is a desirable feature if indigenous fruit tree planting is to be acceptable to farmers (Maghembe 1994). This implies that, a basic understanding of the performance of indigenous fruits in artificial stands is an advanced condition for future planting either in farmers' fields or for commercial purposes. It has also been reported that fruit production in parkland trees vary greatly between species, individuals and from year to year (Breman & Kessler 1995).

In this study, for *B. aegyptiaca* trees with dbh ≥10 cm, the minimum and maximum numbers of fruits estimated by randomized branch sampling at onset and maturity were 12 in (10-19) cm diameter range and 12,288 in (40-49) cm diameter range respectively with an average of (888±20.3) and (2472±111) respectively (**Table 6**). When compared with other studies, the figures for fruit production estimated in this study are slightly higher than a minimum of 268 and maximum of 4,488 with a mean of 1,557 nuts per shea tree in Otuke district in Northern Uganda (Okullo *et al.*, 2004) and a maximum of 1,559 and a minimum of 96 fruits (Filemon, 2017) in Barton.

These estimates being compared were only based on data of fruit counts as with randomized branch sampling (RBS) counts with other studies on different species but further improvements on the current study on fruiting potential of *B. aegyptiaca* can provide acceptable and reliable comparison on desert date fruiting potential. The variation indicated from the estimates therefore, were partly at least due to the different tree sizes and species included in samples, as well as differing microenvironments but not due to differences in methods used for estimating fruits (Okullo *et al.*, 2004). Therefore, the variabilities in this study for fruit production between individuals of similar stem diameter in the *B. aegyptiaca* could be attributed to silvicultural activities (pollarding) during management and field establishments as well as widespread fires that occur annually throughout the study area. Such varying silvicultural practices usually affect the level of fruit production and the availability of pollinators, genetic variation and also diversity in the land use practices (Okullo *et al.*, 2004).

B. aegyptiaca trees being naturally occurring in Napak woodland are preferred and singled or saved during the clearing of fallows into crop fields or settlements by farmers and local people **(Plate 3).** According to (Byakagaba, 2011), these activities have impact on the age, shape of crown and number of desert date trees that remain on a farm as can easily be seen from the size class distribution **(Figure 4)** and variation in the minimum and maximum numbers of fruits produced per tree in this study **(Table 6)**. The impacts of farmers and other related activities in this parkland, together with diversified branching patterns and crown structure of *B. aegyptiaca* (which could also be due to stressful environmental conditions and genetic diversity), requires a technique such as randomised branch sampling to be adopted for making tree crop production estimates (Okullo *et al.*, 2004).

Despite the variations witnessed in *B. aegyptiaca* fruit production, no clear relationship with climatic parameters and other attributes were demonstrated in this study. Thus Potential fruit production tends to increase with tree size and characteristics, although not indefinitely (Boffa, 1999). A correlation was found between tree size (dbh and crown size) and fruit production (Table 9) in all study sites, confirming the findings of Boffa (1995).

Various analyses for fruit production (Table 5 & 6) showed that crown size is an important morphological feature, especially in situations where the community considers intercropping a tree with a food crop in agroforestry **(Plate 3)**. Since crown size determines the area occupied by a tree, light intercepted, and its total photosynthetic area (Chingaipe 1985), the predictions from different analyses gives direct support to the view that high fruit production in *B. aegyptiaca* appears to be associated with specific tree form just like other parkland fruit trees (Boffa 1995).

Much as Schreckenberg (1996) reported that medium sized trees (28-37 cm in dbh) produced significantly more in fields than in the bush. In this study, trees could be in current crop fields, fallows and beside homesteads, with the status of trees sometimes changing from being in the fallows to current crop fields or vice versa before end of fruiting season. As a result, it is thus difficult to make precise judgments on fruit counts between the land uses in a single study like this one. Along term monitoring studies should be required in order to ascertain such judgments on fruit count.

Apart from that, site conditions may also influence yields of fruits; lack of nutrients available for fruit development (fruit fall), flower shed and inter- and intra-specific variation in fruit production (Breman & Kessler 1995). It is important to consider the allometric relationships between crown parameters and fruit load, The tree to tree fluctuations in fruit yields may also result from differential success in pollination and diversity in the genetic make-up of an individual fruit tree (Okullo et al., 2004). In this study, on an individual rachis, an average of about 10-21 fruits were counted and 10-18 (50%-90%) of set fruits matured indicating that about 10-19 (60% average) of flowers produced fruits. This confirms that several other factors are at play to affect actual fruit yields (Okullo et al., 2004).

In this study, fruit yield data, where most trees with high number of fruits were in managed fields and recently fallowed lands compared to those in totally unmanaged sites where most of the trees were found recovering from the previous environmental and human impacts like fires and pollarding activities. This further confirms that fruit production in parkland trees is highly variable between trees, within species, between years as a result of genetic, human and environmental induced factors (Boffa, 1999).

5.3 Ability of B. aegyptiaca to sequester Carbon

Carbon sequestration estimates in Napak woodland (23.3 Mg C ha^{-1}) was higher than from those reported in Tanzania's miombo woodland (19.1 Mg C ha^{-1}) by Shirima *et al* (2011) and Munishi *et al* (2010) and respectively. The differences in maximum and minimum carbon stored among individuals trees in in the different population of 5.15 Mg C ha^{-1} and 2,939.9 Mg C ha^{-1} with mean carbon 5.22 Mg Cha^{-1} and 1168.0±8.7 Mg C ha^{-1} respectively may be attributed to varied human disturbances and land management regimes among study sites (Okia, 2005).

Although the Tanzanian studies by Munishi et al (2010) and Shirima et al (2011) were carried out in the forest reserves, none of them targeted undisturbed or intact plots and measured trees with diameters ≥6 cm (Munishi *et al* 2010) and ≥ 10 cm (Shirima *et al* 2011) unlike the ≥5 cm for this study in Napak woodland. This could have impact on the measured C storage as some trees ≤6 cm are excluded from the Tanzanian measurements. Even then, the estimated carbon from this study is still quiet not related to other results estimated from African tropical rain forests by Dbh classes. For example 202 Mg C ha^{-1} and 350 Mg C ha^{-1} (Lewis et al 2009 and Shear 2004). The estimates of this study are higher than those other estimates because the equations used in this study was developed specifically for the drier tropics and limited and limited to ≥5 cm (Brown *et al*., 1989).

The variations in Carbon storage among Dbh classes of the *B. aegyptiaca* populations could be attributed to the high densities of (20-49) cm Dbh classes with average mean 63.16 and 497.47) than the low (≤10 and ≥50) cm with mean average (5.22 and 1168.87) Dbh classes found under young fallows and crop fields respectively. Though the ability of the *B. aegyptiaca* species to regenerate from coppices and sequester more carbon is not yet reported, this parkland coppice has mainly been through coppice re-growth or saplings as opposed to seeds (Trapnell, 1959).

Those induced factors may partially explain why sites with different dbh classes had higher carbon accumulation than sites exposed to disturbances as witnessed in the variations of size class frequencies (Figure 4). Furthermore, saplings that are usually spared during ground clearance (Byakagaba, 2011) could have contributed to increasing C storage.

The accumulative evidence demonstrated in this study (Table 10) provides empirical evidence of the importance of Napak woodland in carbon sequestration.it also suggests that tropical woodlands can sequester vast amounts of carbon in various eco-regions spreading across different countries, even with differences in edaphic and topographic characteristics (Kalaba *et al.*, 2013). Just like other woodlands, Napak woodland requires promotion of mosaic restoration for local farmers and charcoal producers as patches of this woodland are subjected to different land uses (IUCN 2011). According to (IUCN, 2001 and (WRI, 2011), areas with considerable differences require suitable mosaic restoration in land use) and populations that are between 10-100 persons/km^2 such as Napak woodland.

Through mosaic restoration, degraded patches will recover its lost carbon stocks, biodiversity and provide local communities with arrays of benefits as goods or other eco-system services (Sasaki et al, 2011). Re-growth of vegetation would also play an essential role in offsetting Green House Gas emissions from agricultural, industries and while also conserving biodiversity of native flora (Dwyer et al, 2009), there by producing species that are well adapted to the local conditions in addition to providing habitat suitable for local fauna (Bowen *et al,* 2007).

In order to enhance carbon sequestration in the Napak woodland, there is need to invest in local community participation, long term political commitment, and provision of long-term financial incentives for fallow management under any post-Kyoto agreement. This is so because lack of investment funds can hamper restoration efforts (IUCN, 2011). These restoration efforts are needed to allow locals to generate carbon credits through fallows and further provides opportunities to restore the forest patches that have been depleted and biodiversity which underpins many rural livelihood strategies. To support forest restoration, appropriate national policies, institutional arrangement and local participation are needed (Sasaki et al, 2011). Once this is adopted, under REDD+, managing fallows will be cost effective when compared to conventional planning, but with the challenges of continued monitoring the management of such fallows.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following conclusions have been drawn from the study

a) Size-class distribution has shown disproportionately high numbers of trees of larger Dbh (>25 cm) and relatively few individuals which are between 1-19.5 cm Dbh. Ability of the woodland to continue colonize new areas is indicated with few desert date seedlings and coppice shoots reaching reproductive age. It is also noted that in fallow land regimes, high proportions of annual regenerating shoots present have not developed direct from seeds but coppice from stumps and in most cases the shoots are destroyed by the incessant wild fires and animal grazing.

b) The study has shown that currently the major factors contributing to disintegration of the stand structure in Napak woodland are influenced by land management regimes or trans-human activities (farming, Land grabbing, and urbanization). There is observed transformation to agriculture from pastoralism as the region is now economically and politically opened to the rest of the world.

c) Emerging human impacts: infrastructure development, urbanization and agricultural development have created high pressure on the woodland population with increased demands for fuel wood.

d) Local farmers aim at quick sources of income from growing annual crops like millet, sorghum, maize than enrichment planting that could have helped in restoring the woodland population structure.

e) Productivity in desert date trees (fruit set) in the study populations begins when most individuals reach approximately 9 cm Dbh. Full fruit production levels are reached in trees >20 cm Dbh classes. Mean fruit production was estimated at more than 700 fruits per tree for individuals < 20 cm Dbh and over 10,000 fruits per tree for individuals > 30 cm Dbh.

f) Napak woodland is a substantial above ground Carbon store in the Karamoja sub-region. This is reflected in mean carbon sequestered within the 10-50 dbh categories (63.16±66.8 to1168.87±694.6 Mg Cha^{-1}).

6.2 Recommendations

6.2.1 Management recommendations

There are two management recommendations

i) Since desert date stands of ≥20 cm Dbh classes are adversely affected by human activities (like dry season fires and land clearances during cultivation), there should be fire exclusion, or better, fire management, to maintain fully productive stands of desert date. A way should be devised to reduce combustible materials (grasses and shrubs grown high as result of cattle rustling) which fuels dry season fires.

ii) Early dry season burning is recommended for fallows and productive stands to improve yields by countering the yield reductions which currently result from exposure to wild fire.

6.2.2 Research recommendations

There are two research recommendations

i) Future in depth research on Productivity and Management practices of *B. aegyptiaca* should include monitoring of young desert date individuals (≥5 cm) from the point of seed germination in the main land-use types in Napak woodland, to clarify survival and mortality rates of both regenerating shoots and old individuals.

2 Since pollinator agents like bees can forage over distances (more than 1 km), studies on Reproduction comparing the response to pollen from distant sources (probably > 1 km up to 10 km) from the recipient population are recommended.

REFERENCES

Egweru, A, Clement Okia and Jan de Leeuw. 2014, Trees and Livelihoods of Karamoja.

Azher Nawaz, Waqar Ahhmad, Saeed Ahmad, M. Mumtaz Khan, 2008. Role of growth regulators on preharvest fruit drop, yield and quality in Kinnow mandarin.

Bawa KS & Krugman SL (1991) Reproductive biology and genetics of tropical trees in relation to conservation and management. In: Rainforest Regeneration and Management, Gomez-Pompa, A., T.e. Whitmore and Hadley, M.(eds.), MAB series 6, UNESCO and Parthenon Publishing Group, Paris, pp. 119-136.

Bayala J (2002) Tree crown pruning as a management tool to enhance the productivity of parklands in West Africa. Ph.D. thesis. School of Agricultural and Forest Sciences, University of Wales, Bangor. 202pp.

Binkley, D., J.L, stape, M. G., Ryan, H.R., and J. Fawness, 2002: Age-related decline in forest ecosystem growth, an individual-tree, stand structure hypothesis Ecosystems5:58-67.

Boffa JM (1995) Productivity and Management of agroforestry parklands in the Sudan zone of Burkina Faso, West Africa. Ph.D. Thesis. Purdue University 101 pp.

Boffa JM (1999) Agroforestry Parklands in sub-Saharan Africa. F AO Conservation Guide 34, Rome, 230 pp.

Borchert R (1996) Phenology and flowering periodicity of neotropical dry forest species: evidence from herbarium collections. *Journal of Tropical Ecology* 12: 65-80.

Bowen, M.E., McAlpine, C.A., House, A.P.N., Smith, G.C., 2007. Regrowth forests on abandoned agricultural land: A review of their habitat values for recovering forest fauna. Biol. Conserv. 140, 273-296.

Breman H & Kessler JJ (1995) Woody plants in Agro-Ecosystems of Semi-Arid Regions. Advanced Series in Agricultural Sciences 23. Springer. 340pp.

Brown, S.,Lugo, A.E (1982) The storage and Production of organic matter in tropical forests and their role in global carbon cycle. Biotropica 14, 161-167.

Brown, S., Gillespie., A.J.R., Lugo., A.E (1989) Biomass estimation methods for tropical forests with applications to forest inventory data. For. Sci. 35,881-902.

Bryan, J., Shearman, P., Ash, J., Kirkpatrick, J.B., 2010. Estimating rainforest biomass stocks and carbon loss from deforestation and degradation in papua New Guinea 1972-2002: Best estimates, uncertainities and research needs. J. Environ. Manag. 91,995-1001.

Bullock SH (1995) Diversity and floristic composition of neotropical dry forest. In Seasonality Dry Tropical Forests (Bullock SH, Mooney HA & Medina E (Eds.) pp146-194.

Burd M (1998) 'Excess' flower production and selective fruit abortion: a model of potential benefits. Ecology 79: 2123-2132.

Patrick, B., Gerald, E., John, B.L.O., Suzan, B.T., Edward, N.M., 2011. Population structure and Regeneration Status of *V. Vitellaria paradoxa* (C.F.Gaertn) Under different Land Management Regimes in Uganda. Agric. Jour. 6 (1); 14-22.

Charles Shackleton and Sheona Shackleton, 2004. The importance of non-timber forest products in Rural livelihoods security and as safety nets: a review of evidence from South Africa. South African journal of sci. 100: 551-569.

Chave, J., Condit, R., Anguilar., S., Hernandez., A., Lao., S., Perez, R (2004) Error propagation and scaling for tropical forest biomass estimates. Phil. Trans. R. Soc. Lond. B. 359, 409-420.

Chazdon, R.L., 2003. Tropical forest recovery: legacies of Human impact and natural disturbances. Perspect. Plant Ecol. Evol. Syst. 6, 51-71.

Chazdon, R.L., H.R. Brenes and B.R. Alvarrado, 2005. Effects of climate and stands age on annual tree dynamics in tropical second-growth rain forests. Ecology, 86:1808-1815.

Chaubey, O.P, Sharma, A. 2013. Population Structure and Regeneration Potential of Sal (Shorea robusta gaertn. f.) and its Associates in Sal Bearing Forests of Satpura Tiger Reserve. Int. J. Bio-Sci. Bio-Techn., 5(6): 63-70.

Okia ,Clement Akais, Jacob Godfrey Agea, James Munga Kimondo, Rafaat Ahmed Abohassan, Paul Okiror, Joseph Obua and Zewge Teklehaimanot. 2011 Use and management of *Balanites aegyptiaca* in dry lands of Uganda. Journal of Biological sciences 6 (1): 15-24.

Okia Clement Akais, J. Obua, J. G. Agea & E. Agaro. 2005. Natural regeneration, population structure and traditional management of *Vitellaria paradoxa* subspecies nilotica in the shea parklands of northern and eastern Uganda.Journal of African crop sciences 7, 1187-1191.

Crawley MJ (1986) Life history and environment In Crawley MJ (ed.) Plant ecology. Oxford: Blackwell Scientific Publications. Pp. 253-290.

Dawson 1(1997) *Prunus Africana*: How Agroforestry can help save an endangered medicinal plant. Agroforestry Today. 9: 15-17.

Desmaret J (1958) Observations sur la population de karites de Niangoloko, 1953 A 1957.
OIeagineux, 13 : 449-455.

DGFRN (2010) Quatrie`me rapport national du Benin sur la Convention des Nations Unies sur la Diversite´ Biologique, UNDP.

Diit, E.H., Mourato, S., Ghanzoul, J., Knight, J (2010) Forest conversion and provision of ecosystem services in the Brazilian Atlantic forest. Land Degraded. Dev. 21,591-603.

Dixon, R.K., 1995. Agroforestry systems: sources or sinks of greenhouse gases? Agrofor. Syst. 31, 99–116.

Djossa B, Fahr J, Wiegand T, Ayihouenou BE et al (2008) Land use impact on *Vitellaria paradoxa* C.F. Gaerten. Stand structure and distribution patterns: a comparison of Biosphere Reserve of Pendjari in Atacora district in Benin. Agr Syst 72:205–220.

DOE, 1999. Carbon Sequestration: State of the Science. US Department of Energy (DOE), Washington, DC.

Drury WH (1998) Chance and Change: Ecology for Conservationists. University of California Press.Berkeley. 223pp.

Dupriez H & De Leener P (1989) Land and life: African gardens and orchards-growing vegetables and fruits. MacMillan Publishers in Association with Terres et Vie and CTA. 742pp.

Dwyer, J.M., Fenshman, R.J., Butler, D.W., Buckley, Y.M., 2009. Carbon for conservation: Assessing the potential for win-win investiment in an extensive Australian regrowth ecosystem. Agric. Ecosys> Environ. 134, 1-7.

Errickson R., Georg AS., Marchant NG & Morcombe MK (1973). Flowers and plants of Western Australia. AH & AW Reed. Southampton.

Frost, P., 1996. The ecology of Miombo woodlands. In: Campbell, B (Ed), The miombo in transition: woodlands and Welfare in Africa. Center for international forestry research (CIFOR) Bogor, pp. 11-55.

Gibbs, H.K., Brown, S., Niles, J.O., Foley, J.A., 2007. Monitoring and estimating tropical forest carbon stocks: making REDD a reality. Enviro. Res. Lett. 2, 1-13

Gijsbers HJM., Kessler II & Knevel MK (1994) Dynamics and natural regeneration of woody species in farmed parklands in the Sahel region (province of Passore, Burkina Faso). Forest Ecology and Management, 64: 1-12.

Gupta, J. H, 2012. Vegetation structure, floristic composition and soil nutrient status in three sites of tropical dry deciduous forest of West Bengal, India. Indian J. Funda. App. Life Sci., 2(2): 355-364.

Hall JB, Aebischer PO., Tomlinson HF., Osei-Amaning E & Hindle JR (1996) Vitellaria paradoxa: a monograph. School of Agricultural and Forest Sciences, University of Wales, Bangor, UK. 105pp.

Johnson, R.A. and G.K. Bhattacharyya, 2001. Statistics principles and Methods. 4th Edn., Johnson wiley and sons Inc, New York, USA., pp; 173-178.

Kalaba, F.K., Quinn, C.H, Dougil, AJ and vinya, R (2013) floristic composition, species diversity and carbon storage in charcoal and agricultural fallows and management implications in miombo woodlands of Zambia. Forest ecology and Management, 304. 99-109. ISSN 0378-1127.

Katende, A.B., A. Birnie and B. Tangnas, 2000. Useful Trees and Shrubs for Uganda. Identification, Propagation and Management for Agricultural and Pastoral communities. Majestic printing works Ltd. Nairobi, Kenya.

Kater LJM, Kante S & Buddelman A (1992) Karite (*Vitellaria paradoxa*) and nere (*Parkia biglobosa*) associated with crops in south Mali. Agroforestry Systems, 18 (2): 89-105.

Kessler JJ & Boni J (1991) L'agroforesterie au Burkina Faso: Bilan et analyse de 1a situation actualle. Tropicale Resour. Management Paper No.1. MET, Burkina Faso and Universite Agronomique Wagenigen, Netherlands, 144pp.

Kessler JJ & Breman H (1991) The potential of Agroforestry to increase primary production in the Sahelian and Sudanian zones of West Africa. Agroforestry systems 13:41-62.

Keutgen, N., Chen, K., 2001. Responses of citrus leaf photosynthesis, chlorophyll fluorescence, macronutrient and carbohydrate contents to elevated CO2. J. Plant Physiol. 158, 1307–1316.

Khan JA (1999) Periodicity of major phenophases in woody species in dry deciduous forest of Gir, India. Tropical Ecology 40(2): 299-303.

Lamien, N. and Oudraogo J.S., 2004: Tree potential fruit yield economic local tree species in west Africa Savannah Area, Burkina Faso. 1-36pp.

Lewis, S. L., Lopez –Gonzalez, G., Sonke, B., Affum-Baffoe, K., Baker, T.R., Ojo, L.O., Phillips, O.L., Reitsman, J. M., White, L., Comiskey, J.A., Djuikouo K.M.-N., Ewango, C.E.N., Feldpausch, T.R., Hamilton, A.C., Gloor, M., Hart, T., Hladik, a., Lloyd, J., Lovett, J.C., Makama, J.-R., Malhi, Y., Mbago, F.M., Ndagalasi, H.J., Peacock, J., Peh, K.S.H., Sheil, D., sunderland, T., Swaine, M.D., Taplin, J., Talor, D., Thomas, S.C., Votere, R., Woell, H., 2009. Increasing carbon storage in intact African tropical forests. Nature 457, 1003-U1003.

Lovett, P.N.and N. Haq, 2000. Evidence for anthropic selection of the Sheanut tree (*Vitellaria paradoxa).* Agroforestry syst, 48: 273-288.

Maghembe JA (1994) Performance of multipurpose trees for agroforestry two years after planting at Makoka, Malawi. Forest Ecology and Management, 64 : 171-182.

Malimbwi, R.E., Solberg, B., Luoga, E., 1994. Estimation of biomass and volume in miombo woodland at Kitulangalo Forest reserve, Tanzania. J. Trop. For. Sci. 7, 230-242.

Mass JM (1995) Conversion of tropical dry forest to pasture and agriculture. In: Seasonality dry tropical forests: Bullock SH, Mooney HA & Medina E (eds.) pp. 399-422.

Muchiri, M.N and Chikamai B.N. 2003. Assessment of Fruit Yield: The case of Boabab (*Adansonia digitata*) from the drylands of Kenya, manuscript. 27p.

Munishi, P.K.T., Mringi, S., Shirima, D.D., Linda, S.K., 2010. The role of the Miombo woodlands of the Southern Highlands of Tanzania as carbon sinks. JENE.2, 261-269.

Murali KS & Sukumar R (1994) Reproductive phenology of a tropical dry forest in Mudumalai, southern India. Journal of Ecology 82: 759-767.

MWLE (2000) Ministry of Water, Lands and Environment. The Uganda Forestry Policy (Draft, 2000), MWLE, Kampala-Uganda.

Nasi, R., Wunder, S., Campos, JJ., 2002. Forestry ecosystem services: can they pay our way out of deforestation?, Global Environment Facility (GEF), United Nations Forum on Forestry (UNFF) II, New York.

NEMA (1996) National Environment Management Authority, State of Environment Report for Uganda, Kampala, Uganda, 271 pp.

NEMA (2000) National Environment Management Authority. Uganda National Biodiversity Strategy and Action Plan (Draft). Kampala-Uganda.

Nikiema, A & Umalu, B.E., 2007. *Vitellaria paradoxa* C.F Gaertn. In Van der vossen, H.A.M. & Mkamilo, G. S (Editors). PROTA 14: Vegetable oils Oleagineux [CD-Rom]. PROTA: waeningen, Netherlands.

NRC, 2008. Lost Crops of Africa, Volume III: Fruits: Development, Security and Cooperation Policy and Global Affairs. National Academies Press, Washington DC. ISBN-13: 978-0309105965, pp. 351.

Odebiyi, J.A., S.O. Bada, R.O. Awodoyi, P.I. Oni and A.A. Omoloye, 2004. Population structure of *Vitellaria paradoxa* Gaertn F. and Parkia biglobosa (Jacq) Benth in the Agroforestry parklands of Nigeria humid savanna. West Afri. Applied Ecol., 5:31-39.

Okullo JBL, Hall JB & Eliot M (2003) Reproductive biology and Breeding systems of *Vitellaria paradoxa*. In INCO: International Scientific Cooperation Projects (1998-2002): Improved Management of agroforestry parkland systems in Sub Saharan Africa. Final report: Teklehaimanot Z (Ed). School of Agricultural and Forest Sciences, Bangor, UK. p66-84.

Okullo, J.B.L, Hall, J.B, Obua, J. (2004). Leafing, flowering and fruiting of *Vitellaria paradoxa, subsp niloticum* in the savannaparklands of Uganda; *agroforestry systems* 60:77-91.

Okullo, J.B.L, and G. Wathum, 2007. Diversity and conservation of on-farm woody plants by field types in Paromo sub-county, Nebbi District, North western Uganda, ”*African journal of Ecology, Vol.45,no3,pp 59-66 2007.*

ONUDI (1984). *Balanites aegyptiaca* : possibilités offertes par unematière première inutilisée dans l'agro-industrie, 99 p.

Opler PA (1983) Nectar production in a tropical ecosystem. In Bentley B, Ellias T (eds.) Biology of nectarines, New York, Columbia University Press, 30-79.

Paustian, K., Six, J., Elliott, E.T., Hunt, H.W., 2000. Management options for reducing CO2 emissions from agricultural soils. Biogeochemistry 48, 147–163.

Pouakouyou D (2002) The reproductive biology of Prunus Africana (Rosaceae) on Mount Cameroon and its implications for in situ conservation and management. Ph.D. Thesis. School of Agricultural and Forest Sciences, University of Wales, Bangor, UK

Pullan RA (1994) Framed parkland in West Africa. Savanna, 3 (2): 119-151.

Richards AJ (1997) Plant Breeding Systems (2nd Edition), Bios Scientific Publishers, Chapman and Hall Ltd, London. 544pp.

Robert R. Sokal, F. James Rohlf, W. H. Freeman, 1995. The principles and Practices of Statistics. In Biological Research 4th Edn. 1:75-123.

Sands, M.J.S., 2001. The desert date and its relatives: A revision of the genus Balanites. Kew Bull, 56:1-128.

Sahu, S.C, Dhal N.K, Mohanty R.C, 2012. Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malaygiri hill ranges, Eastern India. Trop. Ecol., 53(2): 163-168.

Sonau, H., N. Picard, P.N. Lovett, M. Dembele, A. Korbo, P. Diarisso and JM. Bovvet, 2006. Phenotypic variation of agronomorphological traits of the shea tree, *Vitellaria paradoxa* GF Gearn inn Mali. Genet Resour crop evaluation, 53:145-161.

Sasaki, N., Asner, G., Knorr, W., Durst, P., Priyadi, H., Putz, F., 2011. Approaches to classifying and restoring degraded tropical forests for the anticipated REDD+ climate change mitigation mechanism. iForest. 4, 1-6.

Schongart, J., Arieira, J., C. Felfili Fortes, Arruda, E.C.d., Cunha, C.N.d.,2008. Carbon dynamics in aboveground coarse wood biomss of wetland forests in northern pantanal, Brazil. Biogeoscience Discuss 5,2103-2130.

Schreckenberg K (1996) Forests, field and markets: a study of indigenous tree products in the
woody savanna of Bassila region. Bennin Ph.D. thesis. University of London. 326 pp.

Sedgley M & Griffin AR (1989) Sexual reproduction in tree crops. Academic Press. London
378pp.

Simons AJ (1997) Tree domestication - Better trees for rural prosperity. Agroforestry Today 9 (2) :3-9.

Shirima, D.D., Munishi, P.K.T., Lewis, S.L., Burgess, N.D., Marshll, A.R., Balmford, A., Swetnam, R.D., Zahabu, E.M., 2011. Carbon storage, structure and composition of miombo woodlands in Tanzania's Eastern Arc Mountains. Afr. J. Ecol. 49, 332-342.

Stephenson, A.G, 1981. Flower and fruit abortion: proximate causes and ultimate functions. Annual Review of Ecology and Systematics 24: 331-351. Stephenson AG (1982) When does outcrossing occur in a mass flowering plant? Evolution 36: 762-767.

Stocklin J & Favre P (1994) Effects of plant size and morphological constraints on variation in reproductive components in two related species of Epilobium. Journal of Ecology 82: 735746.

Strang, R.M., 1974. Some man-made changes in successional Trends on the Rhodesian Highveld. J. Appl. Ecol. 11, 249-263.

Teklehaimanot, Z., 2004. Exploiting the potential of indeginous agroforestry trees; *parkia biglobosa* and *Vitellaria paradoxa* in sub-saharan Africa. Agroforestry.syst, 61:207-220.

Torres C & Galetto L (1999) Factors constraining fruit set in Madevilla pentlandiana (Apocynaceae). Botanical Journal of the Linnean Society 129: 187-205.

Traore´ KB (2003) Le parc a` karite´: sa contribution a` la durabilite´ de l'agrosyste`me. Cas d'une topose´quence a` Konobougou (Mali-Sud). The`se de doctorat: Sciences du sol, CIRAD, Montpellier, pp 1–216.

Uganda Bureau of Statistics 2017, The National Population and Housing census 2014-area specific profile series, Kampala, Uganda.

UNDP (United Nations Development Programme), 2014. Karamoja-Napak District hazard, risk and vulnerability profile.

USDA NRCS (United States Department of Agriculture Natural Resources Conservation Service), 2000. Growing carbon: a new crop that helps agricultural producers and the climate too. Available from the Soil and Water Conservation Society. http://www.unl.edu/nac.

Vogt K (1995) A Field Workers' Guide to the Identification, Propagation, and Uses of Common Trees and Shrubs of Dryland Sudan: *Vitelllaria paradoxa* pp 116-117. 50s, Sahel International, UK 167pp.

Walker, S.M., Densianker. P.V., 2004. The impact of land use on soil carbon in Miombo Woodlands of Malawi. For. Ecol. Manag. 203, 345-360.

Wilson P, Thomson, Stanton ML & Rigney LP (1994) Beyond floral Batemania: gender biases in selection for pollination success. Ameican Naturalist 143: 283-296.

WRI, 2011. Opportunities for forest and landscape restoration in Africa. World resources Institute. Available at: http://www.wri.org/map/opportunities-forest-and-landscape-restoration-africa

Data collection sheet for the study in Napak woodlands

Transect No:……………………………………… Plot No:……………..

Date:…………………………..

Number of trees	Dbh (cm)	Total Branch Number	Fork number	Estimated fruit No on a branch	Total estimate	Canopy diameter	Tree character

QUESTION GUIDE FOR ASSESSMENT OF FRUIT PRODUCTION AND CONSERVATION PRACTICES FOR *BALANITES AEGYPTIACA* IN NAPAK WOODLAND, MOROTO DISTRICT, NORTH-EASTERN UGANDA.

Category……………………………… **parish……………………………...** **village………………**

Section A: **<u>Assessment of fruit production success of desert date under varying management practices.</u>**

2a) State the major land uses where desert date is found or around Napak woodland

i)…………………………………………… ii) ………………………………………. iii)………………………………………. iv)………………………………………….

b) How long do you fallow the piece of land that you have? 1 year [ ] 2 years [ ] 3 years [ ] >5 years [ ]

c) How many fruiting seasons are there in a year? once [ ] twice [ ] thrice [ ]

d) Under which land use practices does desert date drop flowers and premature fruits? Wild [ ] compound [ ] cultivated farms [ ]

e) Why do you think it happens as stated above? I)…………………………………………. ii)……………………………………… iii) ……………………………………………….

f) Describe some of the factor to high flower production in desert date ………………………………………………………………………………………………… ………………………………………………………………………………………………… …………….

g) What are some of the factors which promotes high fruit production in desert date in the different land use categories?

i)……………………………………………… ii) …………………………………………

iii)………………………………………………. iv) ……………………………………………

h) Describe some of the factors you think can greatly cause flower/ premature fruit drop in desert date tree…

i)………………………… ii) ………………………iv……………………………

I) what are the effects of any bee keeping activities on the yield of desert date in your area

……………………………………………………………………………………………………
……………………………………………………………………………………………………

j) Which land improvement strategies do you practice so as to improve yield of desert date?

Fertilizers [ ] goats/ cow dung [ ] Mulching [ ] Return of food/crop residues [ ]

k) Describe any other indigenous technical knowledge that local farmers employ to manage desert date tree for high fruit production

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Section B: Farmers local knowledge on Traditional management and conservation practices or strategies for improved fruit production in desert date.

2a) What are some of the conservation practices carried out by the locals towards conserving the tree species?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………..

b) Have you ever been told by anybody or organisation on issues related to wise use of the tree species from the woodland? Yes [ ] No [ ]

If yes, what are some of the advice?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………..

If no, what do you think or suggest should be the good way of conserving the tree in the woodland?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………

c) Why is the community cutting other tree species and instead conserve desert date?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
………

d) Is desert date disappearing from the woodland compared to the past years? Yes [ ] No [ ]

If yes, why? …………………………………………………………………………………………………
…………………………………………………………………………………………………

e) State the effect of other tree growing near desert date tree on its yield.

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

f) Do you prune the desert date tree? Yes [ ] No [ ]

If yes, what are the benefits of pruning desert date/ ekorette?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

i) Are there any local by-laws that are in place favoring desert date conservation and fruit production?

Yes [ ] No [ ]

If yes, state some of them

…………………………………………………………………………………………………
…………………………………………………………………………………………………

j) Describe the effects of the following:

i) Effect of fires on desert date/ekorette

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

ii) Effect of grazing on desert date

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

iii) Effect of charcoal burning on desert date.

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

k) Is there any authority in place responsible for the management of the woodland? Yes [ ] No[ ]

If yes, do you have any problem with them? Yes [ ] No [ ]

If yes, what are some of them?

....

....

L) How has the management authority like the District forest services, National Forestry Authority or Non-Governmental Organisations affected/influenced you towards conservation of desert date both on farm and in wild?

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

m) Do you find any problems in utilizing and protecting desert date in recent years? Yes [ ]

No [ ]

If yes, what measures/ suggestions do you have for continued conservation of desert date? ....

....

....