

**THE DISTRIBUTION AND BUNDANCE OF ENDANGERED DESERT DATE (*Balanites
aegyptiaca*) AND ITS CONSERVATION MEASURES IN KATAKWI DISTRICT**

BY

ASIKU JIMMY

17/U/14351/GMSM/PE

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DECLARATION

This thesis is my original work and has never been presented for a degree in any other University.

Signature:.....

Date:.....

Asiku Jimmy

17/U/14351/GMSM/PE

APPROVAL

We as University supervisors confirm that the work was done by the candidate under our supervision.

Signature:.....

Date:.....

Dr. Asio Santa Maria

Principal Supervisor

Signature:.....

Date:.....

Dr. Ssanyu Grace Asiyu

Second Supervisor

DEDICATION

This dissertation is dedicated to my mother Mrs. Florence Asune who without attaining any formal education supported and encouraged me throughout my studies, my brother Mr. Apangu Phillipam and nephew Mr. Oguzu Evan who motivated and inspired me in various ways and finally to my late father Mr. Agobia Andrew who laid the foundations for my studies.

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TABLE OF CONTENTS

DECLARATION	i
APPROVAL	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	v
LIST OF FIGURES	ix
LIST OF TABLES	x
LIST OF ABBREVIATIONS	xi
ABSTRACT	xii
CHAPTER ONE	1
INTRODUCTION	1
1.0 Background	1
1.1 Problem Statement	3
1.2 Objectives	4
1.2.1 General objective	4
1.2.2 The specific objectives of the study are to:.....	4
1.3 Research Questions	5
1.4 Justification of the research	5
1.5 Significance of the research	6
1.6 Scope.....	7
CHAPTER TWO	8
LITERATURE REVIEW	8

2.0 Indigenous fruit trees	8
2.1 <i>Balanites aegyptiaca</i> Tree.....	8
2.2 Abundance of <i>Balanites aegyptiaca</i> and its associated Species.....	10
2.3 Biology, chemistry, and medicinal values of <i>Balanites aegyptiaca</i>	10
2.4 Utilization of <i>Balanites aegyptiaca</i> by the local communities	12
2.5 Regeneration and Harvesting of <i>Balanites aegyptiaca</i>	13
2.6 Land cover Land Use change effect on Indigenous Fruit Trees	13
2.7 Conservation and management practices of IFTs by local communities	15
CHAPTER THREE	17
MATERIALS AND METHOD	17
3.0 Description of study area	17
3.1 Research design	20
3.2 Methods of Data Collection	20
3.2.1 Distribution of <i>Balanites aegyptiaca</i> in Katakwi district	20
3.2.2 Abundance of <i>Balanites aegyptiaca</i> and its associated trees in Katakwi district	21
3.2.3 Utilization, effects of leaf harvesting methods and land cover land use change on regeneration of <i>Balanites aegyptiaca</i>	21
3.2.4 Local conservation and management practices of <i>Balanites aegyptiaca</i>	23
3.3 Data analysis	24
3.3.1 Distribution of <i>Balanites aegyptiaca</i> in Katakwi district	24
3.3.2 Utilization, effects of leaf harvesting methods and land cover land Use change on the regeneration of <i>Balanites aegyptiaca</i>	26
3.4 Conservation and management practices of <i>Balanities aegyptiaca</i>	26

3.5 Ethical Consideration.....	27
3.6 Limitations	28
CHAPTER FOUR.....	29
RESULTS	29
4.0 Distribution of <i>Balanites aegyptiaca</i> in Katakwi district	29
4.1 Abundance of <i>Balanites aegyptiaca</i> , <i>Vitex madiensis</i> and <i>Acacia seyal</i> in the study area	31
4.1.1 Relative dominance of <i>Balanites aegyptiaca</i> , <i>Vitex madiensis</i> and <i>Acacia seyal</i>	33
4.1.2 Influence of harvesting on distribution (dbh), abundance and relative dominance.....	34
4.2 Utilization, effects of leaf harvesting methods and Land cover Land Use change on regeneration of <i>Balanites aegyptiaca</i>	36
4.2.1 Utilization of <i>Balanites aegyptiaca</i> by local communities	36
4.2.2 Methods of harvesting and frequently used methods	38
4.2.3 Relationship between methods of harvesting and natural regeneration of <i>Balanites aegyptiaca</i>	40
4.3 Land cover Land Use change in last 40 years in the study area	41
4.4 <i>Balanites aegyptiaca</i> harvested during dry and rain season on daily basis	43
4.4.1 Local threats to the population <i>Balanites aegyptiaca</i>	44
4.5 Conservation, Management Options and Socio-Economic Importance of <i>Balanites aegyptiaca</i>	45
4.5.1 Local conservation measures used by community to conserve <i>Balanites aegyptiaca</i>	45
4.5.2 Management options and Institutional involvement used by the local community to conserve <i>Balanites aegyptiaca</i>	46
CHAPTER FIVE	48

DISCUSSIONS.....	48
5.1 Distribution of <i>Balanites aegyptiaca</i> in Katakwi district	48
5.2 Utilization, effects of leaf harvesting and Land cover Land Use change on the regeneration of <i>Balanites aegyptiaca</i>	50
5.3 Conservation, Management and Socio-Economic Importance of <i>Balanites aegyptiaca</i>	53
CHAPTER SIX	55
CONCLUSIONS AND RECOMMENDATIONS.....	55
6.1 Conclusions.....	55
6.2 Recommendations	55
REFERENCES.....	57
APPENDICES	71
APPENDIX 1: PHOTO GALLERY S	71
APPENDIX 2: FIELD PROTOCOL	72
APPENDIX 3: RESEARCH QUESTIONNIARE	73
APPENDIX 4: FOCUS GROUP GUIDE—VILLAGE COMMUNITY MEETINGS.....	80
APPENDIX 5: OBSERVATION CHECKLIST	83
APPENDIX 6: SAMPLING FRAMEWORK	84
APPENDIX 7: KREJCIE AND MORGAN (1970) TABULATION.....	85
APPENDIX 8.....	86

LIST OF FIGURES

Figure 3.1: A map showing sub-counties and villages of study area.....	19
Figure 3. 2: Different pictures of <i>Balanites aegyptiaca</i> distributed in the study area. A- <i>Balanites aegyptiaca</i> tree un-harvested, B – harvested <i>Balanites aegyptiaca</i> , C – research team establishing a plot, D – fairly disturbed area of <i>Balanites aegyptiaca</i>	23
Figure 4. 1: Basal area distribution of <i>Balanites aegyptiaca</i> per plot sampled	31
Figure 4. 2: Dominance of <i>Balanites aegyptiaca</i> , <i>Vitex madiensis</i> and <i>Acacia seyal</i>	34
Figure 4.3: The percent utilization of the <i>Balanites aegyptiaca</i> by the local communities in Katakwi district	37
Figure 4. 4: Pictures of Methods of harvesting <i>Balanites aegyptiaca</i> captured in the field: A- branch lopping, B – Tree felling, C – Leaf plucking directly from the tree and D – use of ladder to pluck leaves.....	39
Figure 4. 5: Correlation between the methods of harvesting and regeneration of <i>Balanites aegyptiaca</i> . A – Tree felling; B – Branch lopping C –Leaf plucking directly from the tree and D- Use of ladder to pluck leaves	40
Figure 4. 6: Land cover land use change map of Ongongoja and Ngariam sub counties between 1979 and 2019.....	43
Figure 4. 7: Population of <i>Balanite aegyptiaca</i> harvested during dry and rain season	44
Figure 4. 8: Local threats to <i>Balanites aegyptiaca</i> in Katakwi district	45
Figure 4.9: Community suggested interventions to conserve the <i>Balanites aegyptiaca</i>	46

LIST OF TABLES

Table 3. 1: Sub-Counties and villages of the study area.....	18
Table 4.1: Summary of <i>Balanites aegyptiaca</i> diameter at breast height distribution (in).....	30
Table 4.2: Abundance and relative abundance of <i>Balanites aegyptiaca</i> , <i>Vitex madiensis</i> and <i>Acacia seyal</i> in the study area	32
Table 4.3: Ranking of species by dominance (% contribution to plot basal area) in the 6 plots..	33
Table 4.4: Regression model predicting the rate of tree harvesting based on abundance, relative dominance, and diameter at breast height.....	35
Table 4.5: Descriptive Statistics of rate of tree harvesting based on abundance, relative dominance and diameter at breast height	36
Table 4.6: Benefits and most beneficial part of <i>Balanites aegyptiaca</i> used by the local community	37
Table 4.7: Percentage number of trees harvested per method	38
Table 4.8: Percentage Change of Land cover Land Use change in the last 40 years	42
Table 4.9: Institutional involvement and Management options to conserve <i>Balanites aegyptiaca</i> ..	47

LIST OF ABBREVIATIONS

DBH	Diameter at Breast Height
FAO	Food and Agricultural Organization of the United Nations
IFTs	Indigenous Fruit Trees
IUCN	Union on Conservation of Nature
NEMA	National Environment Management Authority
NRC	National Research Council (US)
NTFPs	Non-Timber Forest Products
RA	Relative Abundance
STD	Standard Deviation
UBOS	Uganda Bureau of Standards
UNIDO	United Nations Industrial Development Organization
WCS	Wildlife Conservation Society

ABSTRACT

The global importance of Indigenous Fruit Trees as natural resource to meet the nutritional, health and socio-economic needs of rural communities cannot be ignored. *Balanites aegyptiaca* is among the most frequently used IFTs by local communities in Africa for food and medicine. This study was therefore conducted to understand the distribution, abundance, utilization, regeneration and conservation measures of *Balanite aegyptiaca* in Katakwi district. The objectives were to understand the; (i) distribution; ii) abundance and its associated species; (iii) utilization, methods of harvesting and land use land cover change effect on its generation and (iv) conservation and management practices. Quadrats were established to determine the distribution, abundance, and regeneration while Focus Group Discussion, questionnaires, observations, and photography were used to collect data on utilization, methods of harvesting threats, regeneration, conservation and management practices. GIS/Remote Sensing was used to obtain satellite imageries to depict land use land cover status of study area. Data was analyzed in SPSS and excel. Distribution was analysed from diameter at breast height (dbh) data while abundance was analysed by comparing different species data. Descriptive statistics such as mean was used to analyse utilization and conservation measure. The result showed that *Balanites aegyptiaca* with large dbh (33, 29 and 25) were the most distributed and low abundance of *Balanites aegyptiaca* was recorded compared to the *Vitex madiensis* L. and *Acacia seyal* Del. Further, relative dominance was a significant predictor for rate of *Balanites aegyptiaca* harvested while distribution and abundance were not. There was a 55.5% increase in the mean number of trees harvested for each extra abundant species available. A significant number of respondents (68.6%) agreed that *Balanites aegyptiaca* is utilized by communities. A strong positive correlation existed between regeneration and, cutting down ($r=0.850$, $p=0.003$) and cutting off branches methods ($r=0.768$, $p=0.01$) while no correlation existed between picking the leaves directly ($r=0$, $p=0.05$) and climbing to pick the leaves ($r=0$, $p=0.05$). *Balanites aegyptiaca* is mainly used for food, medicine, source of income and fuel. The conservation measures included sensitization clan byelaws, cultural norms, controlled grazing and on farm retention. The study concluded that the distribution of *Balanites aegyptiaca* in study area is dominated by mature/old trees. There is low abundance of *Balanites aegyptiaca* as compared to *Vitex madiensis* and *Vitex madiensis*. The forest cover change over the years has reduced and other land uses are taking over. The local communities significantly utilized *Balanite aegyptiaca* to improve their socio-economic status. In general, the local community was worried that *Balanite aegyptiaca* population was reducing and fear it will get extinct if the current trend of harvesting cannot be reversed. Alternative sources of livelihoods need to be sought for the community to give the tree an opportunity to regenerate. The study recommended that the community needs to be supported to promote *Balanites aegyptiaca* into dry land agroforestry systems, the less harmful methods of harvesting needs to be promoted. Further study needs conducted to understand the *Balanites aegyptiaca* distribution along moisture gradient of the landscape which may offer an opportunity to restore degraded wetlands and a detailed study to assess its genetic diversity is needed to ascertain which sub species is more threatened to prioritize conservation efforts.

CHAPTER ONE

INTRODUCTION

1.0 Background

Indigenous Fruit Trees (IFTs) are part of many vital wild and agricultural systems that support the livelihood of many farmers all over the globe (Awodoyin , *et al.*, 2015). Their importance to meet the needs of rural community household nutrition, health and socio-economic needs may not be underestimated and ignored (Leakey, 2020; Omotayo & Aremu, 2020). IFT such as *Balanites aegyptiaca (L) Del* are among the earliest wild plant resources used as food by humans since the development of agriculture (Leakey & Ajayi, 2007). The species is widely distributed in the arid and semiarid areas (Sawadogo, *et al.*, 2017). It colonizes a range of soil types from sand to heavy clays including river soils along riverbanks (Ahmed, *et al.*, 2020). It is frequently used by the local communities (Mohammed, Ndakidemi, & Treydte, 2021) for socio economic benefits such as food, income, medicine among others (Fadl, 2015; Abdelrahim, 2015).

In Africa, the species has lost their natural habitat due to human activities such as deforestation emanating from population growth (Cemansky, 2015). Even though the humans have destroyed them for their survival, the continent has continued to flourish in abundance and distribution of IFTs valuable to its citizens for diets and income during hard times (Cemansky, 2015). They are managed and conserved by local farmers in their community forest reserves, traditional home gardens and protected volunteer stands (Awodoyin , *et al.*, 2015). Many methods of managing their regeneration have been practiced by the benefiting communities for long period time and these include coppicing, seedling protection from browsing animals and farm retention among others (Idrissa, *et al.*, 2018). However, the population has continued to decrease across Africa due to human activities such as animal browsing on the palatable tender seedlings and saplings and

wildfire by hunters and cattle keepers (Sanon, Kaboré-Zoungrana, & Ledin, 2007; Kochare, Tamir, & Kechero, 2018; Ball & Tzanopoulos, 2020). Humans have destructively exploited the parts of the tree such as stems, leaves, bark, roots, and seeds for their own benefits (Ssegawa & Kasenene, 2007; Gustafsson, *et al.*, 2012; Suleiman, *et al.*, 2017). However, much pressure it has received from the human disturbance, the species is abundantly distributed in the tropics and has continued to provide ecological and socio-economic benefits to humans since its domestication (Awodoyin, *et al.*, 2015).

In Uganda, the IFTs such as *Balanites aegyptiaca* (L) Del have been threatened with extinction like they are being threatened in other parts of Africa such as Sudan (Ogwali, Agea, & Okullo, 2016). The fact that *Balanites aegyptiaca* (L) Del is mostly found in north and north-eastern part of the country due to arid and semi-arid nature of the regions, its utilization and consumption has remained destructive by the local communities (Okia, 2010) and it is over harvested for consumption (Oryema, Oryem-Origa, & Roos, 2015). The species is genetically diverse and distributed abundantly in dry areas of Uganda from Karamoja through Teso, West Nile and to Kasese district even though its population has been tempered by man (Okia, 2010). The low population of the species has affected the food security stability and economy of the local communities that have depended on it for long period of (Kalinganire, Weber, Uwamariya, & Kone, 2007). The local communities have tried to conserve the species within their means especially those from west Nile and north-eastern Uganda but due to hard times, they have continued to destructively harvest the species (Eilu, Oriekot, & Tushabe, 2007). Subsistence agriculture has been the favourable biodiversity conservation method however this has remained a big challenge as demand for land has increased (Eilu, Oriekot, & Tushabe, 2007). On farm retention among other practices is just a small part of the practice used to conserve the species

(Agea, Obua, Kaboggoza, & Waiswa, 2007), however the practice is becoming scarce due to unsustainable land management practice (Buyinza, *et al.*, 2015).

Due to human's ways of excessively harvesting the species, they are now threatened with extinction (Ogwali, Agea , & Okullo, 2016) and limited attention from research, policy and development is making the situation worse (Adebooye & Opabode, 2004). For example, they have been labelled as wild in South Africa causing stigmatization leading to decline in their knowledge (Akinola, Pereira, Mabhaudhi, de Bruin, & Rusch, 2020). On the other hand, no study has discovered that the species is threatened with extinction (Musotsi, Sigot, & Onyango, 2003). Due to lack of research and development, it has been underutilized for development of rural communities (NRC , 2008).

It was therefore important that studies like this one was conducted given the fact that *Balanites aegyptiaca* (L) Del is destructively utilized by the local communities in Katakwi district where it grows and hence understanding its ecological and social economic status whose outcomes were used to recommend the conservation and management actions.

1.1 Problem Statement

Buyinza, *et al.*, (2015) reported that the most important species will suffer the greatest harvesting pressure from local communities. *Balanites aegyptiaca* as an Indigenous Fruit Trees in Teso community is utilized for food, medicine, wood fuel and parts utilized include leaves, fruits, barks, and roots. Eighty percent (80%) of rural communities derive their livelihood such trees (Campbell & Holt, 2001). Its regeneration is very poor due to over harvesting, bush fires and goat browsing amongst others. On the other hand, the vegetation has decreased from 11% to 7% in Katakwi district (Mary & Diisi , 2014). Okia, (2010) reported that *Balanites aegyptiaca* is negatively

affected by over-harvesting and some die as a result. Tabuti & Mugula, (2007) reported high underutilization due to limited knowledge and yet it contributes towards environmental stability, food security and poverty alleviation. The tree is feared to be endangered due to over harvesting for livelihood purposes, animal browsing, bush burning among others (Yougouda, Dorothy, Michel, & Marie, 2018) hence, a threatened species at the edge of extinction. Katende, Birnie, & Tengnäs, (1995), reported limited information and reliable methods for measuring its contribution to local communities. No studies in Uganda have been done to reveal the distribution, abundance, utilization, and conservation of *Balanites aegyptiaca* status in Uganda and in particular Katakwi District. It is likely that *Balanite aegyptiaca* will go extinct if studies are not done. The purpose of the study was to determine the distribution and abundance of *Balanites aegyptiaca*, how community utilization is affecting its regeneration capacity and communities' conservation and management of the tree. The findings of this study are expected to initiate local and national conservation measures and good management practices.

1.2 Objectives

1.2.1 General objective

To assess how the distribution and abundance of *Balanites aegyptiaca* was affected by its utilization and determine the how the species is been utilized and conserved by the local communities in Katakwi District

1.2.2 The specific objectives of the study are to:

1. Determine the distribution of *Balanites aegyptiaca* in Katakwi District.
2. Quantify the abundance of *Balanites aegyptiaca* and its associated tree species (*Vitex madensis* and *Acacia seyal*)

3. Examine the utilization, effects of leaf harvesting methods and Land cover Land Use change on the regeneration of *Balanites aegyptiaca*
4. Identify the conservation and management practices of *Balanites aegyptiaca* used by the local communities in Katakwi District

1.3 Research Questions

1. What is the distribution pattern of *Balanites aegyptiaca* in terms of diameter?
2. What is the abundance of *Balanites aegyptiaca* and its associated trees (*Vitex madensis* and *Acacia seyal*)?
3. How is *Balanites aegyptiaca* utilized in Katakwi district and what are the effects of its utilization, land cover land use and leaf harvesting methods on its regeneration?
4. What are the conservation and management practices of *Balanites aegyptiaca* by the local communities in Katakwi district?

1.4 Justification of the research

Balanites aegyptiaca is a highly consumed indigenous tree in Katakwi district Okia, (2010), however, it is believed that the gene pool has reduced and genetic erosion is occurring within and between natural populations (Elfeel, 2011). To save the species from the extinction, an effective conservation strategy urgently needs to be put in place to address the genetic erosion that is taking place. However, such conservation strategies cannot be realized unless the whole spectrum of the issues surrounding its utilization, reproduction, population structure among others is fully understood. Okullo *et al.* (2004) reported that conservation and development strategies for IFTs cannot be realized unless detailed knowledge of its productivity and conservation strategies is available. This study therefore sought to determine the distribution, abundance, utilization, regeneration and conservation and management practices of *Balanite aegyptiaca* in Katawi

district. When implemented, the recommendations from this study can increase the chances of sustaining the species. This can also address the biodiversity crisis of extinction the world is faced with. The outcomes of this study will directly contribute to achievement of Sustainable Development Goal such as poverty alleviation, protection of Life on Land and Climate Action through increasing forest coverage, reducing carbon, reducing biodiversity extinction among others.

1.5 Significance of the research

This study will provide the general public with valuable information on the distribution, abundance, utilization, regeneration, conservation and management practices of *Balanites aegyptiaca*. This information is expected to be used to inform the community and general public on status of the tree and which conservation actions should be taken. The information generated will provide evidence for policy makers to formulate policies both at local and national level and implement them to ensure the conservation of *Balanites aegyptiaca* to encounter its extinction. This study will also act as baseline and source of information for other researchers and can be used to validate conservation of *Balanites aegyptiaca* in the country. The study findings will also trigger further conservation research in areas that are identified to be researched further. This study will increase knowledge on the already known facts about conservation of endangered species in the country with specific facts about *Balanites aegyptiaca* as an indigenous fruit trees. The results will also be used to ensure the continuity of continuum of conservation work especially in the Uganda in the context of indigenous fruit trees in dry lands. The study is a requirement for the completion of the Master's Science Degree in Conservation and Natural Resource Management.

1.6 Scope

The study was carried out in Ongongoja and Ngariam sub counties in Katakwi district. The research studied the abundance, distribution, utilization, regeneration, size and height, methods of harvest, benefits, conservation and management practices of *Balanites aegyptiaca* used by the local communities in Katakwi district. The research was conducted between the months of December, 2018 and May 2019.

CHAPTER TWO

LITERATURE REVIEW

2.0 Indigenous fruit trees

Indigenous Fruit Trees (IFTs) by definition, are native species to a region or place where they originated and evolved over long period time (CTA, 2007). Human have consumed them both from the wild and at domestic level for their survival (CTA, 2007). They are widely distributed in the African dry lands from Ethiopian Sahelian transition zone to dry and humid parts of east, west and central africa (Kiambi & Atta-Krah, 2003). In Uganda, other than shear butter tree (*Vitalleria paradoxa*), other IFTs such as *Balanites aegyptiaca* are not purposefully planted by farmers or even promoted by research and most grow on their own in the wild due to limited knowledge of their benefits (Agea, Obua, Kaboggoza, & Waiswa, 2007). The lack of attention from research and development has resulted in decreased abundance and distribution in the natural vegetation especially in the east African region (Goenster, *et al.*, 2009). The main challenges they face include over exploitation for human socio-economic needs, constant habitat loss, urbanization and introduction of toxic species (Kahane, *et al.*, 2013). Other than human interference, climate change has caused shift in their natural ranges hence reducing their density and productivity (Dawson, Jackson, House, Prentice, & Mace, 2011). Apart from the challenges and decreasing abundance, they have continued to supplement the rural community diets especially in sub Saharan Africa (Akinnifesi, *et al.*, 2006), amongst the poor and vulnerable rural population (Akinola, Pereira, Mabhaudhi, de Bruin, & Rusch, 2020).

2.1 *Balanites aegyptiaca* Tree

Balanite aegyptiaa also known as Desert date (Del.) is a spiny shrub/tree belonging to the family of Zygophyllaceae and genus *Balanites* which is widely distributed in Africa and south Asia and

utilized as indigenous fruit/vegetable tree (Chothani & Vaghasiya, 2011). It consists of twenty-five (25) different species (NRC , 2008) colonizing arid and semi-arid soils and humid Savana areas (NRC , 2008) with vast geographical distribution (Berhaut , 1979; Arbonnier, 2000; Sagna , Niang, Guisse, & Goffner, 2014). It is adapted to wide range of climate, habitat and other environmental conditions for survivability (Janick & Paull, 2008; Reubens, et al., 2011) and it is very tolerant to wild fire especially the mature ones (Hall & Walker, 1991). It grows on its own or some times by famers in gardens (Chothani & Vaghasiya, 2011)

Distribution of *Balanites aegyptiaca*

Balanites aegyptiaca is a woody species that is widely spaced with large crown and at times clumped crowns entangled in one place (Hall, 1992). Its distribution is either by naturalization or cultivation both in the wild and farms (Chothani & Vaghasiya, 2011). It is widely distributed in Africa especially in the dry lands (Tesfaye, 2015) and can survive in any soil condition though it likes to colonize swampy areas/along rivers and lowlands (Orwa, Mutua, Kindt, Jamnadass, & Simons, 2009). It grows at an altitude of 2,000, mean annual temperature between 20-30°C and mean annual rain fall of 250-400mm (Orwa, Mutua, Kindt, Jamnadass, & Simons, 2009). Orwa, Mutua, Kindt, Jamnadass, & Simons, (2009) found that the species is highly adaptable to extreme climatic conditions such as temperature, wind, drought, and light. Despite its wide distribution in arid and semi-arid regions, the species remain neglected in terms of research (Ouédraogo, Ouédraogo, Thiombiano , & Boussim, 2021) and hence its distribution is not known and understood for decision making.

In Uganda, it is common in the north east districts, lowland areas of West Nile along the River Nile, the flat plains of Lake Albert, shores of Lake Kyoga and the dry margins of Queen Elizabeth National Park (Eggeling, 1940' Katende, Birnie, & Tengnäs, 1995). Some studies have reported

its scanty occurrence outside the nice area (Agea, Obua, Kaboggoza, & Waiswa, 2007). In Teso sub region, the species is distributed along swamps and is composed of mainly mature ones with low recruitment capacity due to human impact (Okia , 2010). Other dominant IFTs in Teso sub region include; *Carissa spinarum* L., *Strychnos innocuous* Delile, *Balanites aegyptiaca* (L) Delile, *Tamarindus indica* L., and *Ximenia Americana* L (Ojelel, 2019).

2.2 Abundance of *Balanites aegyptiaca* and its associated Species

The abundance of IFTs is attributed to ecological location (Chomba & Sianjobo , 2016) and studies have shown that when the conditions are right, their abundance may exceed 25 ha⁻¹ which is normally a rare situation (Hall, 1992). The abundance of species increases with genetic variations and geographic range. Genetic variations have been observed in nine species of *Balanites aegyptiaca* (Elfeel & Warrag, 2011). It has been observed to be the most abundant tree species in semi-arid region of Uganda (Okia , 2010). It is usually found mixed with *Acacia Seyal* in what is known as the *Acacia seyal - Balanites aegyptiaca* Savana, in the wide tropical belt of Africa (Orwa, Mutua, Kindt, Jamnadass, & Simons, 2009). A close association with *Vitex madiensis* Oliv, *Carrisa spinarum*, *Ximenia americana*, and *Tamarindus indica* was found in Teso-Karamoja sub region (Ojelel, et al., 2019).

2.3 Biology, chemistry, and medicinal values of *Balanites aegyptiaca*

The flowering of the tree varies from location to location and most of times the flowering takes place in dry season (Orwa, Mutua, Kindt, Jamnadass, & Simons, 2009). It exhibits slow growth at early stages making it vulnerable to goat browsing and wild fire (Okia , 2010). Similary the fruiting and folliage also occur at the same period of the season (Orwa, Mutua, Kindt, Jamnadass, & Simons, 2009). The pollination is by insects since the flowers are scented and fruits takes about 1years to mature and ripe (Orwa, Mutua, Kindt, Jamnadass, & Simons, 2009). Theflowers open at

night between 3-6am and the pollen is released in big amounts which lasts for 4 days (Okia , 2010). It is affected by pests such as bruchid beetles which bores in the seeds which reduces its regeneration (Okia , 2010).

B. aegyptiaca produces a variety of secondary metabolites, such as polyphenols (phenolic acids, flavonoids and coumarins), alkaloids, steroids, saponins (spirostanol saponins, furostanol saponins and open-chain steroidal saponins) and pregnane glycosides, isolated from plant tissues, such as fruit, seeds, leaves, stem bark, roots and galls. The tree is rich in oil accounting for 46% of its weight (Mohammed, Wolf, & Spiep, 2002), 7,10% of protein 13% amino acids (Okia , 2010) and contains saponins and flavonoids in the fruit mesocarps used in manufacturing of drugs and animal feeds (Chapagain, Hoekstra, Savenije, & Gautam, 2006). The tree also contains useful amount of zinc (8.3 mg/drywt) for maintainance of human body immunity.the main fatty acid includes plamitic (15.4%), stearic (19.01%), oleic (25.74%) and linoleic (39.85%) wich are very important nutrinet values of food. The overall energy value is 346.82 kcal/100 g. Fruits are also rich in minerals, including calcium, magnesium, phosphorus, potassium, and sodium. Iron, copper, manganese, lead, chromium, cobalt, cadmium and selenium are reported in lower concentrations. The pulp is rich in carbohydrates (62.63%) and protein (9.19%) and also exhibits amino acids and vitamins.

Plants synthesize several antimicrobial compounds, including phenolics such as simple phenols, phenolic acids, quinones, flavonoids, flavones, flavonols, tannins, coumarins, terpenoids, essential oils and alkaloids (Cowan, 1999). The mechanism of action of these compounds ranges from membrane disruption, substrate deprivation, intercalation into the cell wall/or DNA and enzyme inhibition Cowan, (1999). Desert date is rich in all these phytochemicals and demonstrates potent antimicrobial activity (Ganesan, Jayachandran, & Xu, 2018). The bark of *B. aegyptiaca* is widely used in African folk medicine for the treatment of wounds and skin diseases (Ganesan,

Jayachandran, & Xu, 2018). The effects of aqueous ethanolic extracts of bark on bacteria isolated from wounds have been reported (Ganesan, Jayachandran, & Xu, 2018). Among the plant-based bioactive compounds, saponins and phytosterols have significant importance in reducing the risk of cancer (Speroni, et al., 2005). The tree also exhibits potent anti-inflammatory activity; where the extracts exhibited a significant reduction of rat paw edema (Speroni, et al., 2005).

The species is propagated through seed and the germination is hypogeal where its hypocotyl do not elongate (Fadl, 2015). Stem propagation has also been reported by some studies accounting for 60% survival rate (Okia , 2010). For better germination, the seeds need to be sown horizontally in the soil (Fadl, 2015). For quick germination, the seeds need to be soaked in water for hours to separate the stones from the pulp or immersed in hot water for about 7-10 minutes (Fadl, 2015). However, the natural regeneration has been affected by the high demand for the fruits which has high economic value hence leaving few or no seeds for natural regeneration.

2.4 Utilization of *Balanites aegyptiaca* by the local communities

Balanites aegyptiaca is valuable tree to many dry land communities in Africa (Sands, 2001). In some parts of the continent such as Uganda, the local communities rely on it for food, income, fodder, construction material and medicine (Aliou, 2014). The leaves are believed to be good for mulching (FAO, 1992) while the fruits and leaves are eaten during shortage food by the local communities (Katende, Birnie, & Tengnäs, 1995; NRC , 2008; Teklehaimanot, 2008). (Okia , 2010) found evidence of consumption of young tender leaves of *Balanites aegyptiaca* in Katawi district during food shortage. The species produce hard wood used commonly by the local communities for making household wooden items such as hoe handle (Sands, 2001). It produces good firewood and its charcoal produces less smoke which makes it user friendly for the locals (Webb, Cushing,

& Wright, 1984). The branches are used for fencing and the protein rich young leaves and shoots are an excellent source of fodder for livestock (NRC , 2008).

2.5 Regeneration and Harvesting of *Balanites aegyptiaca*

Balanites aegyptiaca has good natural regeneration, sprouts well and coppice freely (El-Nour, 1994). Its regeneration is through seeds and coppicing though the one through seed is more prevalent (Okia , 2010). In communities where its harvesting is common, the harvested stand is left to coppice naturally (Ky-Dembele, Tigabu, Bayala, Ouédraogo, & Odén, 2007). It also has ability to produce through suckers and the off springs from the suckers grow faster than other methods (Brokensha & Riley, 1980) can can regenrate faster after haevy regeneration (Wani, Sahrawat, Sreedevi, Bhattacharyya, & Rao, 2007). (Elfeel & Warrag, 2011) observed a very high regeneration in Sudan though there was also high disturbance from animal trembling. Even though, the regeneration is good, the species is believed to be endangered (Elfeel & Warrag, 2011). Not all the hopes are lost as there are operations by the local and development parties to restore the species. (Elfeel & Warrag, 2011) found that the local community in Sudan were restoring the species through farmer managed regeneration.

2.6 Land cover Land Use change effect on Indigenous Fruit Trees

More than 80% of the rural population derive their livelihoods from the indigenous fruit trees and woodlands such as *Balanites aegyptiaca* through permanent and shifting cultivation, charcoal and timber production, and the harvesting and sale of Non-Timber Forest Products (Campbell., *et al*, 2007]. Human activities are resulting into degradation of these trees inclusive of *Balanites aegyptiaca* and cover loss, as well as loss in fauna, flora and woodland ecosystems (Schreckenber *et al.*, 2016). Human activities, especially the conversion and degradation of habitats, are causing global biodiversity declines (Majaliwa *et al.*, 2018). The notable activities include the cutting down

of trees, charcoal burning and poor farming methods, among others, which undermine the functionality of ecosystems (Majaliwa *et al.*, 2018). The rapid conversion of natural vegetation, for example, to farmlands, could be attributed to farming techniques and agronomic approaches that aim at modern agricultural intensification (Majaliwa *et al.*, 2018). In Uganda, land use/cover change is an environmental challenge (Mbogga *et al.*, 2014; USGS, 2015). The rate of land use/cover change was estimated at 7% in 1990 and now stands at 11% with eastern Uganda registering the highest rate of 20% (UBOS, 2011; Mary *et al.*, 2014). The main land cover Land use in Teso sub region include wetlands, lakes, forest, woodland, bush land, built up areas (UIA, 2016). Katakwi district which is found in the region is dotted with shrubs and trees, dominated by *Balanites aegyptiaca*, *Acacia*, *Combretum*, *Piliostigma*, *Butyrosperum paradoxum* and *Hyperenia species* lies in the same sub region (UIA, 2016). The sub region is blessed with a number watersheds and Awoja watershed in which Katakwi District falls in Kyoga Water Management Zone of eastern Uganda with an area of 10 km² is a key watershed degradation hotspot with a perceived degradation rate of 76% as compared to 63% from Lake Victoria crescent and 41% in the south western farmlands of Uganda (NEMA, 2008; Nelson *et al.*, 2013). The watershed supports over 1,700,000 individuals that derive their livelihood from it, with a contribution of over USD 200 as earnings from papyrus harvesting and mat making per household annually (IUCN, 2005; Richard *et al.*, 2009). Akello *et al.*, (2016), reported increased change in built up areas and open waters in the sub region in the period of 2007 to 2013. The tree cover change reduced from 139.63 to 91.56 km² representing a 34.46% decrease and agricultural land cover category reduced by 114 km² (from 223.35 to 109.35 km²), a reduction of 51.05% (Akello *et al.*, 2016). In the last two decades, several strategies including sensitization, training, tree planting, establishing soil and water conservation structures were put forward by both the government and development partners

to protect and restore the degraded watersheds (Ministry of Water and Environment, 2013; World Bank, 2013;). In spite of this, the Teso sub region continues to face increasing degradation, even with government and development partner efforts to restore it (Akello *et al.*, 2016). UNDP, (2016) reported poor land use, fires set deliberately to clear forest or pasture for agricultural purposes and other unsustainable ecosystem exploitation that lead to deterioration of the environment Although, studies conducted within watershed indicate failure in restoration efforts due to high population growth and increased demand for watershed resources, little is known about the magnitude of this change in terms of land use/cover (Mutekanga *et al.*, 2013; Mbogga *et al.*, 2014). Unless the extent of degradation in Awoja is known then will government and development partners devise appropriate approaches for restoration (Akello *et al.*, 2016).

2.7 Conservation and management practices of IFTs by local communities

Harvesting of wild species for socio economic benefits has been the tradition of local communities for long period of time (Akinnifesi, *et al.*, 2006). Farmers value IFTs and have continue to manage them in their farms for asset building through approaches such as farmer managed regeneration (Atta-Krah, Kindt, Skilton, & Amaral, 2004; Akinnifesi, *et al.*, 2006). Okia *et al.* (2011) reported that households in Katakwi district retained and protected regenerants of *Balanites aegyptiaca* in their farms and home steads. Retention of low-density valuable trees in the farms in the semi-arid areas is a common practice (Akinnifesi, *et al.*, 2006). In southern Tanzania, Akinnifesi *et al.* (2006) reported that farmers spare fruit trees such as *Uapaca kirkiana* and *Parinari curatellifolia* because of their importance to households.

However, some studies have noted that farmers have not deliberately cultivated IFTs in their farms due to cultural believes and lack of knowledge on propagation techniques (Schreckenber, *et al.*, 2006). Campbell & Holt, (2001) reported that there is need to understand the evolution and

dynamics of institutions in order to develop IFTs. Other studies have recognized that there need to integrate formal institutions with traditional, moral and political legitimacy at the local level to provide a more stable and effective approach for managing trees and other natural resources (Oduol, Ajayi, Matakala, & Akinnifesi, 2008). Other studies have suggested that innovations such as value addition can stimulate farmers to conserve IFTs such as *Balanites aegyptiaca* (Okullo, Hall , & Obua, 2004). Another solution would be to improve the socio-economic situation of farmers to avoid reliance of IFTs for survival (Schreckenber, *et al.*, 2006).

CHAPTER THREE

MATERIALS AND METHOD

3.0 Description of study area

The study was conducted in Katakwi District in the eastern part of Uganda. It was conducted in sub-counties of Ongongoja and Ngariam. Katakwi District (Figure 1 and Table 1) which lie between longitudes of 33° 48' E - 34° 18' E and latitudes 1° 38' N – 2° 20' N (Figure 3.1). The district borders with Napak in the North, Nakapiripirit in the East, Amuria in the West and North-West, and Soroti in the South –West, Kumi and Ngora in the South. Katakwi district experiences bimodal seasons that is wet and dry seasons. Wet season begins from March - October and a dry season begins from November - February. The mean annual rainfall varies from 1000mm - 1500mm. The rainy season is at the peak due around March - June and a minor peak around August - October. December and January are usually the driest months. Recent rainfall has been unreliable and unpredictable.

The district sometimes registers extremes of both very heavy rainfall and drought. In some cases heavy rainfall is accompanied by hailstones. Water logging as a result of heavy down pour is sometimes experienced in many areas, especially in Ngariam and Magoro sub-counties. Katakwi District records a mean annual maximum temperature of 31.3°C and a mean minimum of 18°C. Relative humidity ranges from 66% to 83% at 0600 GMT in the morning, and 35% - 57% at 1200 GMT, thereby reducing chances of rainfall (KDL, 2015). The soils are mainly of sandy sediments and sandy loam. Bottomland contains widespread deposits of alluvium. The land resource is fertile and productive. The most fertile areas lie in the North to Eastern part of the district (UNDP, 2009). The vegetation of Katakwi district is largely savannah grasslands dotted with shrubs and trees, dominated by *Acacia*, *Conbretum*, *Piliostigma*, *Butyrosperum paradoxum* and *Hyperenia* species

(Katakwi District Development Plan, 2015-2020). The district population according to 2014 census report was 166,231 of which 81,673 (49.1%) are male and 84,558 (50.9%) are female (UBOS, 2016). Traditionally many of the people of Katakwi District are pastoralists, earning their livelihoods through livestock rearing and crop production at subsistence level. This became difficult in 1986 when cattle rustling by the Karimojong intensified and in 1987 civil strife in the Teso region aggravated the situation (UNDP, 2009).

Table 3.1: Sub-Counties and villages of the study area

Sub counties	Villages
Ongongoja	Angorekit Okuda B Anyangabela
Ngariam	Amutoro Acoite Bisina

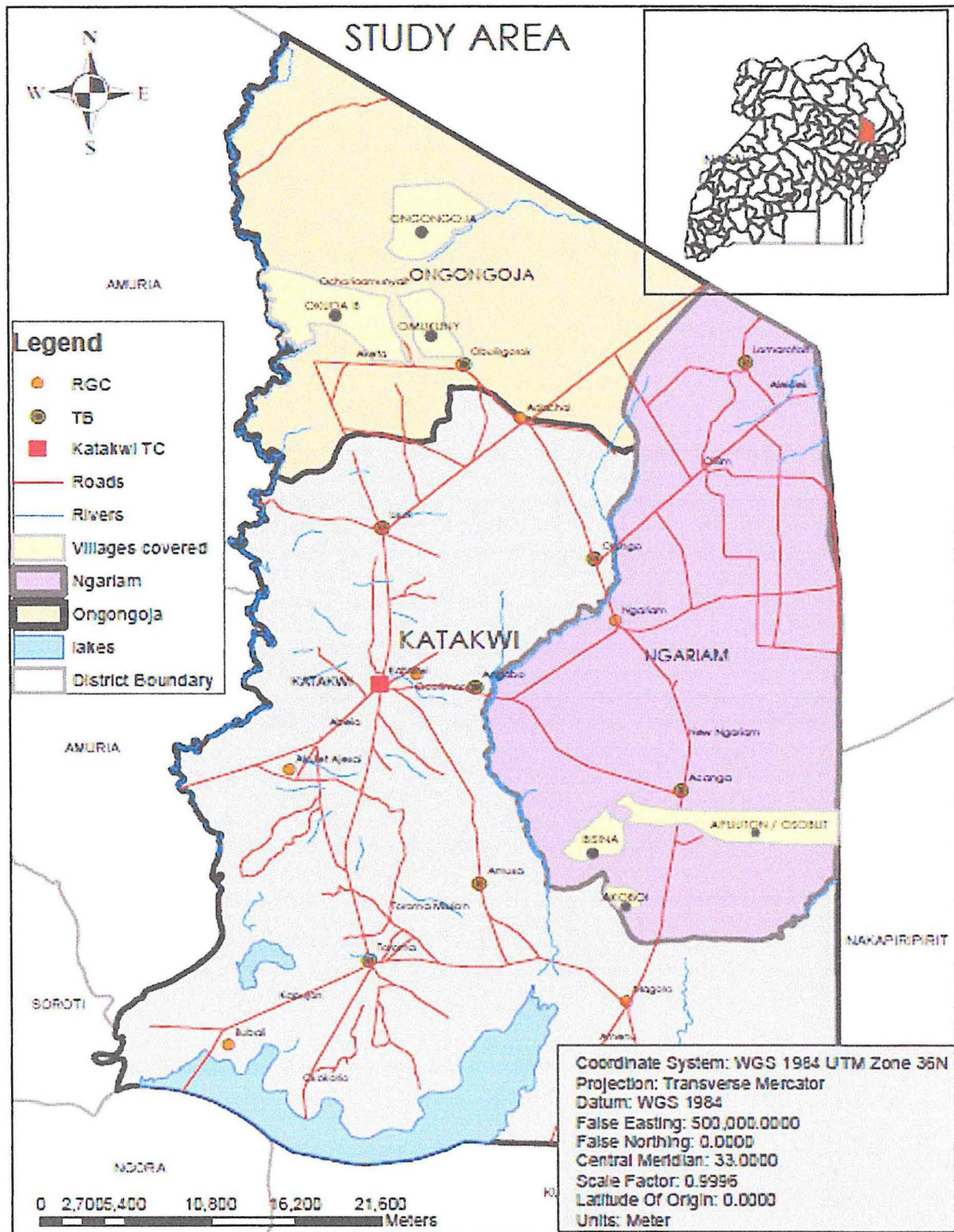


Figure 3.1: A map showing sub-counties and villages of study area

3.1 Research design

The study used quadrats to determine the distribution and abundance of *Balanites aegyptiaca* and its associated species. An inventory of felled and harvested trees was conducted to assess the regeneration of the species. Photography, observation and recording was used during the inventory of the felled and harvested trees. A desk review through use of Geographical Information Systems (GIS)/Remote Sensing was used to determine the land cover land use change by downloading and analysing the satellite images of the study area. Socioeconomic tools such as Focus Group Discussion and questionnaires were developed and used to collect data on utilization and harvesting methods. The same tools were also used to collect data on conservation and management practices used by the local communities. The study district (Katakwi district) was selected based on personal experience of how *Balanites aegyptiaca* supported the local food security and yet the stocking level seemed not be sufficient to meet the local demand. The sub-counties and villages were purposively selected based on recommendation of District Forestry and Sub County officials on the availability and use of *Balanites aegyptiaca* products such leaves, roots, barks, leaves, and kernel oil.

3.2 Methods of Data Collection

3.2.1 Distribution of *Balanites aegyptiaca* in Katakwi district

The study established quadrats of 100*100m² randomly to determine the distribution of *Balanites aegyptiaca*. A field protocol (appendix 2) was used to help guide the process of establishing plots during data collection in the study area. The data collection approach was adopted from Gouwakinnou, Kindomihou, Assogbadjo, & Sinsin, (2009) who described young plant with basal diameter (at ground level) less than 1 cm were considered as seedlings and those with stem greater than 1 cm basal diameter or more than 1 m height but less than 5 cm diameter at breast height

(dbh) and/or less than 1.5 m height was considered as saplings. For each quadrat, number of individual trees, diameter at breast height and height were counted and recorded. The number of the trees, sapling and seedling and dbh were recorded on a datasheet. The data was collected both in dry and wet season for comparison purposes.

3.2.2 Abundance of *Balanites aegyptiaca* and its associated trees in Katakwi district

A quadrat of 100x100 m² was laid out randomly to determine the number of each species present and the experiment was replicated in other six villages of the study area. A 100x100m quadrat was due to the large size off the tree and wide distribution of the species. An inventory of the species present was then taken and recorded following a procedure designed in the study protocol. Local names of the species were sought from the local communities which were used to identify the species. Katende, Birnie, & Tengnäs, (1995) handbook on useful trees and shrubs of Uganda was used to identify the species.

3.2.3 Utilization, effects of leaf harvesting methods and land cover land use change on regeneration of *Balanites aegyptiaca*

Focus Group Discussions (FGD) (details in 3.3.3 below) and questionnaires were carried out to determine the utilization, methods of harvesting and local threats by the communities. Six FGD were organized with community members and each category of the community group was separately interviewed. Questionnaires were administered to district and sub county officials (Sub County chief, Community Development Officers, Parish Chiefs and Local Councils) to provide informed information on the utilization, methods of harvesting and local threats while FGDs were used to validate the data from the questionnaires by the asking the participants the same questions.

String quadrats were established to conduct inventory of the felled and harvested trees across the landscape randomly.

The same plots were used to conduct the inventory of the trees that were regenerating and those that were not. Observation was used to determine the method of harvesting in the same quadrats established. All the information was recorded in data sheet and used for further analysis. Geographical Information Systems (GIS)/Remote Sensing was used to collect data about land cover land use change through downloading satellite images. ArcGIS (10.2) program was used to acquire satellite imagery data of land cover of forest areas and compared it to other land covers such farmland, built area, grassland in terms of trends of increase and decline. Landsat 8 Operational land imager (OLI) and Landsat 1-5 were used to acquire the images from freely accessed website of the United States Geological Survey online imagery portal (Tahiru, Doke, & Baatuuwie, 2020). Handheld GPS devices were used for ground truth verification to determine the number of dominant species and other crucial land uses for the research area to guide in performing the producer's accuracy (Schilling, Jha, Zhang, Gassman, & Wolter, 2008).

Photographs of different events of interest such as relief, trees harvested, places of charcoal burning, animal browsing on the *Balanites aegyptiaca*, community harvesting methods and land use changes were taken from the field. The photographs were transferred to the computer, interpreted and used in the comparing and remembering events during the report writing.

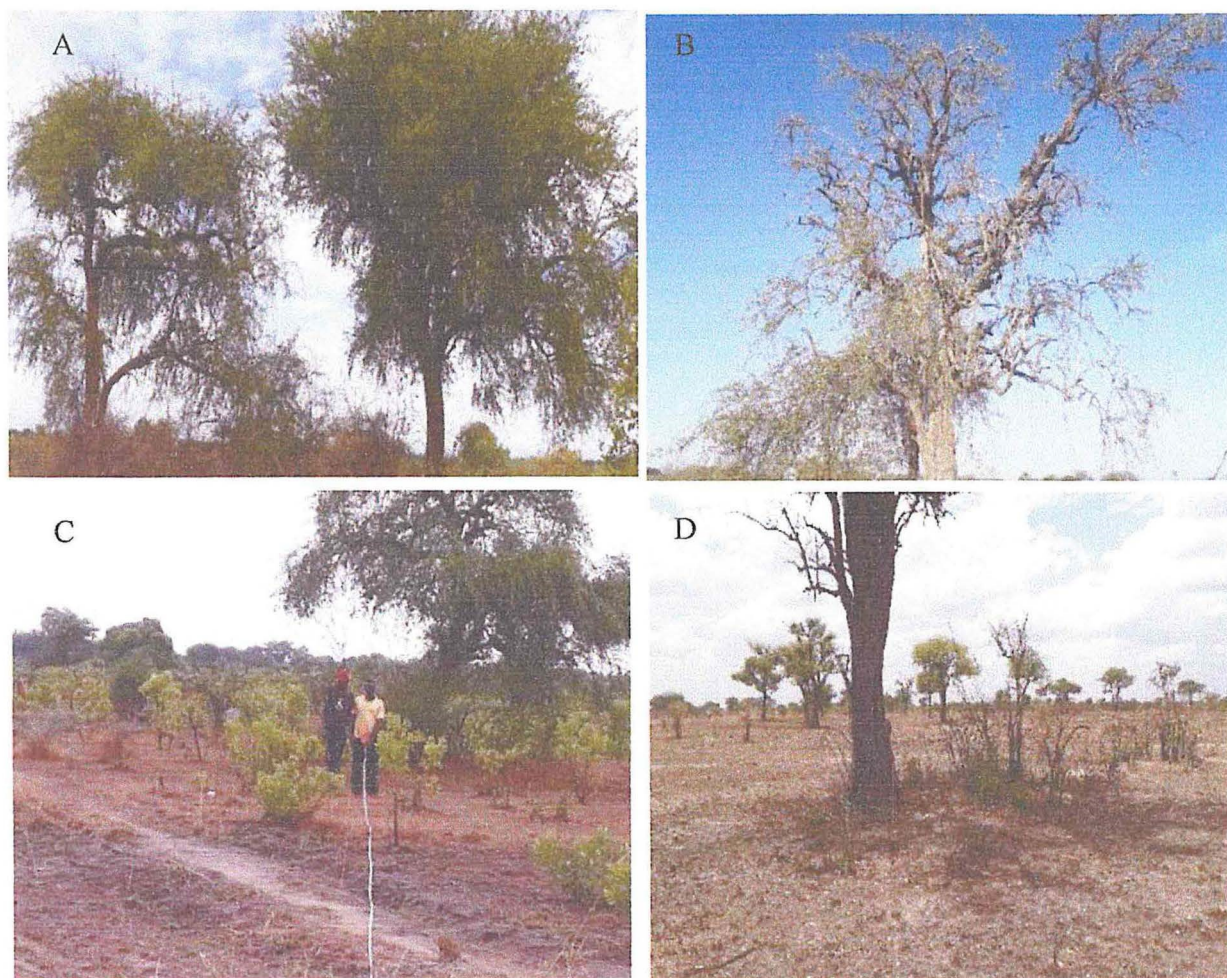


Figure 3.2: Different pictures of *Balanites aegyptiaca* distributed in the study area. A- *Balanites aegyptiaca* tree un-harvested, B – harvested *Balanites aegyptiaca*, C – research team establishing a plot, D – fairly disturbed area of *Balanites aegyptiaca*

3.3.4 Local conservation and management practices of *Balanites aegyptiaca*

The social economic survey was conducted through Focus Group Discussion (FGD) (appendix 4) and questionnaires (appendix 3). A sampling framework (appendix 6) was used to determine the sample number of the study participants. Focus groups included ten (10) members such as women, young adolescent girls and elderly persons. Discussions were about local conservation and management practices of *Balanites aegyptiaca*. This was conducted in 6 villages that were

purposefully selected with the help of local authorities based on their knowledge and experience regarding the *Balanites aegyptiaca*. The study administered seventy (70) questionnaires for the study survey. Respondents included community leaders, Local Government officials and local people. Random sampling was used to select the community leaders and elders while purposive sampling was used to select the local government officials. Krejcie & Morgan, (1970) tabulation (appendix 7) was used to determine the sample size of the participants and villages.

3.3 Data analysis

3.3.1 Distribution of *Balanites aegyptiaca* in Katakwi district

Distribution of *Balanites aegyptiaca* was analysed by summarizing diameter at breast height (dbh) of different trees recorded. The dbh was arranged in ascending order from small to big dbh for each quadrat which was used to calculate the Basal area (BA). Basal area per tree (square feet) was calculated as $0.005454 \times (\text{dbh})^2$ for all the trees sampled. Student t tests analysis were carried out to determine differences in distribution from one village to another.

Abundance of *Balanites aegyptiaca* and its associated trees in Katakwi district

The study compared the abundance of *Balanite aegyptiaca*, *Vitex madiensis* and *Acacia seval* from the sampled area. The number of species per plot was summed up to determine the abundance of each species. Relative abundance was computed in percentage to compare it with absolute abundance of the species. The summarized data was presented in tables for easy presentations. Species relative dominance was calculated as a percentage of the contribution of the species to the basal area. This was used to rank species for each plot and compare species dominance among plots established and this also helped to identify dominant species in each quadrat.

Poisson regression was used to analyse the effect of abundance, relative dominance, and diameter at breast height on number of trees harvested. Poisson regression is one of the generalized linear models that is used to predict a dependent (response) variable that consists of "count data" given one or more independent variables. The model assumes the following: 1) the response variable consists of count data which follow a Poisson distribution; 2) the observations are independent of one another; 3) the mean of the response variable is approximately equal to its variance (Dobson & Barnett, 2018). The relationship between the response and predictor variables is expressed as:

$$\log(\lambda_i) = \beta_0 + \beta_1 \mathbf{Abundance} + \beta_2 \mathbf{Dominance} + \beta_3 \mathbf{DBH} \quad \text{for } i = 1, 2, \dots, n$$

Where λ_i = average number of trees harvested (mean harvest rate); β_0 = intercept (constant); β_i = coefficients/parameters to be estimated (The exponent of β_i represents a percentage change in the counts of the response variable due to a unit change in the independent variable; *Abundance* = number of individual species in a sample; *Dominance* = number of abundant species. In order to test for model adequacy, the likelihood ratio (LR) test was used as a measure of goodness of fit. It tests the null hypothesis that the estimated model is a poor fit by checking whether all the independent variables collectively improve the model in comparison with the intercept-only model. If the null hypothesis holds, the likelihood ratio approximates a chi-squared distribution χ^2 with p degrees of freedom where p is the number of parameters in the model. Large values of the likelihood ratio indicate good (significant) fit.

3.3.2 Utilization, effects of leaf harvesting methods and land cover land Use change on the regeneration of *Balanites aegyptiaca*

The data was entered in excel sheets for different variables that ranged from, utilization, methods of harvesting, historical population of the tree and threats. Mean, standard deviation and standard errors were used to analyse the utilization data. Furthermore, the utilization, methods of harvesting and threat were analysed using student t-test and chi-square tests statistical analysis to determine levels of significance. The study used correlation analysis to establish association of harvesting methods and regeneration.

Land use and land cover change was detected by using post classification detection method. This was performed by use of ArcGIS Software to determine any change in matrix. Quantitative aerial data of the overall land use land cover changes as well as gains and losses in each character between 1979 and 2019 was compiled (Matshakeni, 2016). Change detection analysis of land use change was done using pixel-by-pixel assessment of land use maps generated from satellite image classification, change matrix was created to show quantitative information of changes visually represented on an image map (Cheruto, Kauti, & Kisangau , 2016). The analysis and interpretation of different aspects of the numeric data of LULC dynamics was done in Microsoft Excel using the pivot table as results were presented in form of maps.

3.4 Conservation and management practices of *Banalities aegyptiaca*

The socioeconomic survey data also was entered in excel and SPSS for analysis the data entered included community perception on local conservation and management options and benefits. Data was transformed in to means presented in the form of tables and pie charts.

3.5 Ethical Consideration

The following ethical guidelines were put into place for the research period:

1. The researcher obtained a letter of introduction from Head of Department, Biological Sciences, Kyambogo University to conduct research.
2. The researcher obtained clearance from the “Chief Administrative Officer” of Katakwi District to conduct research in the district. This was followed by courtesy visits to different sub-county chiefs and local leaders for proper introduction and commencement of data collection.
3. The researcher trained the research assistants on the objectives of the study and how to be professional by seeking consent before taking pictures and interviewing someone. The study exercised voluntary participation of respondents in the research survey. Participants had rights to withdraw from the study at any stage if they wished to do so.
4. Survey respondents participated on the basis of informed consent. Participants were given sufficient information and assurances about taking part in the study. Individuals were allowed to understand the implications of participating in the study and reach a fully informed decision whether to take part in the study without the exercise of any pressure or coercion.
5. The research data remained confidential throughout the study and the researcher obtained the participants’ permission to use their real names in the research. The dignity and wellbeing of the participants was protected at all times. The use of offensive, discriminatory, or other unacceptable language was avoided in the formulation of the questionnaire.

6. The researcher engaged both males and females during the data collection. Views from both sexes were listened to with maximum attention and used as part of the findings from the field to write report.

3.6 Limitations

Thick vegetation during the ecological survey hindered the appropriate establishment of the plots and quadrats especially during the second phase of the data collection. The dry season did not favour the result the regeneration or regrowth of the tree. It also affected results on germination of seeds. However, the data collection was done twice one in dry season to avoid the limitation from the thick vegetation and another at the beginning of the rain season when the seeds were germinating and coppices were regenerating.

CHAPTER FOUR

RESULTS

4.0 Distribution of *Balanites aegyptiaca* in Katakwi district

The research recorded the number of trees and basal area in each plot under the study area (Table 4.1). The study determined the distribution of *Balanites aegyptiaca* in diameter at breast height (dbh).

The result showed that the sampled *Balanites aegyptiaca* trees with dbh 33, 29 and 25 (in) were the most distributed class while those with dbh 21 (in) were common in almost all the plots (5/6) and those with dbh 14 and 6 (inches) were rare. There was no significant difference in the number of *Balanites aegyptiaca* distributed $t(11.07) = 5, p > 0.05$ among trees sampled. ($\chi^2 =$ chi square, $d.f =$ degrees of freedom)

Table 4.1: Summary of *Balanites aegyptiaca* diameter at breast height distribution (in)

Quadrats	DBH (inches)	No. of Trees	BA per tree (m ²)	Total BA (m ² /ha)	Total BA Mean (\pm SE)
1	14	1	1.07	1.07	7.5 \pm 4.7
	21	1	2.41	2.41	
	25	1	3.41	3.41	
	29	1	4.59	4.59	
	31	5	5.24	26.21	
2	21	3	2.41	7.22	9.9 \pm 4.3
	25	2	3.41	6.82	
	29	1	4.59	4.59	
	31	4	5.24	20.97	
3	14	1	1.07	1.07	5.8 \pm 1.8
	21	1	2.41	2.41	
	25	3	3.41	10.23	
	29	2	4.59	9.17	
	33	1	5.94	5.94	
4	6	2	0.20	0.39	6.2 \pm 2.2
	21	2	2.41	4.81	
	25	3	3.41	10.23	
	29	2	4.59	9.17	
5	21	2	2.41	4.81	8.8 \pm 3.2
	25	1	3.41	3.41	
	29	2	4.59	9.17	
	33	3	5.94	17.82	
6	14	1	1.07	1.07	8.6 \pm 3.3
	17	1	1.58	1.58	
	25	3	3.41	10.23	
	29	4	4.59	18.35	
	33	2	5.94	11.88	

DHB–Diameter at Breast Height; *BA*–Basal Area; *TBA*–Total Basal Area; *SE*–Standard Error;

Total number of plots = 6

The study noted that *Balanites aegyptiaca* in quadrats 2 and 5 had largest Total Basal Area (TBA) while the ones in quadrats 1, 3 and 4 had moderate TBA and those in quadrat 6 had smallest TBA

(Figure 4.1). Distribution in quadrats 2 and 5 were dominated by *Balanites aegyptiaca* that were big enough while those in 1, 3 and 4 had mixed of different tress sizes and the ones in plot 6 were dominated by tress small sizes.

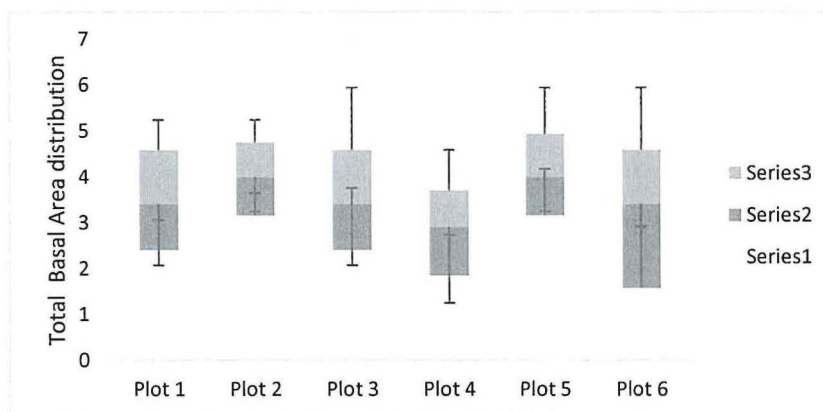


Figure 4. 1: Basal area distribution of *Balanites aegyptiaca* per plot sampled

4.1 Abundance of *Balanites aegyptiaca*, *Vitex madiensis* and *Acacia seyal* in the study area

The study result showed that *Vitex madiensis* was the most abundant species followed by *Acacia seyal* while *Balanites aegyptiaca* was lowest abundant species in Ongongoja Sub County (Table 4.2 below). In Ngariam Sub County, *Vitex madiensis* recorded the most abundant species followed by *Balanites aegyptiaca* and *Acacia seyal* recorded lowest abundant species. There was no significant difference in the abundance among the species studied ($\chi^2=11.07, d.f=5, p>0.05$). The relative abundance of the *Balanites aegyptiaca* was low compared to other two species in both Sub Counties while *Vitex madiensis* had high relative abundance in both Sub Counties. The study recorded a non-significant difference in relative abundance between the species studied ($\chi^2=11.07, d.f=5, p>0.05$). However, considering the sampling based on plots established, no single species was significantly abundant throughout the study area. In some instances, *Balanites aegyptiaca* was more abundant in some plots compared to other species and vice versa for the other species.

Table 4.2: Abundance and relative abundance of *Balanites aegyptiaca*, *Vitex madiensis* and *Acacia seyal* in the study area

Sub Counties	Quadrats	<i>Balanites aegyptiaca</i>			<i>Vitex madiensis</i>			<i>Acacia seyal</i>		
		Abundance	Mean (\pm S.E)	RA	Abundance	Mean (\pm S.E)	RA	Abundance	Mean (\pm S.E)	RA
	1	9		0.02	71.0		0.12	32.0		0.06
Ongongoja	2	20	9.17 \pm 2.52	0.03	197.0	52.67 \pm 30.65	0.34	39.0	33.83 \pm 19.79	0.07
	3	12		0.02	21.0		0.04	122		0.21
<i>Total %ge</i>				6.9			49			33.3
	4	5		0.01	4.0		0.01	3.0		0.01
Ngariam	5	3		0.01	4.0		0.01	4.0		0.01
	6	6		0.01	19.0		0.03	3.0		0.01
<i>Total %ge</i>				2.9			4.9			2.9

RA = Relative Abundance, S.E = Standard Error

4.1.1 Relative dominance of *Balanites aegyptiaca*, *Vitex madiensis* and *Acacia seyal*

The results indicated that out of the six quadrats sampled, *Vitex madiensis* dominated four, *Acacia seyal* and *Balanites aegyptiaca* dominated one each (Table 4.3). *Vitex madiensis* had relative dominance of 40.9% and an average basal area of 87.5 m² ha, *Acacia seyal* had 30.9% and an average basal area of 62.2 m² ha and *Balanites aegyptiaca* had the lowest relative dominance (28.1%) and an average basal area of 60.0 m² ha (Figure 4.2 below). The results indicated a non-significant difference in the basal area of species ($\chi^2 = 7.81, d.f=5, P>0.05$). The mean basal area of the trees was 7.75 ± 2.99 for *B aegyptiaca*, 4.40 ± 0.35 for *V. madiensis* and 6.02 ± 0.87 for *A. seyal* respectively.

Table 4.3: Ranking of species by dominance (% contribution to plot basal area) in the 6 plots

Plot 1	%	Plot 2	%	Plot 3	%	Plot 4	%	Plot 5	%	Plot 6	%
<i>VM</i>	64	<i>VM</i>	77	<i>AS</i>	79	<i>BA</i>	42	<i>VM</i>	40	<i>VM</i>	68
<i>AS</i>	28	<i>AS</i>	15	<i>VM</i>	14	<i>VM</i>	33	<i>AS</i>	30	<i>BA</i>	21
<i>BA</i>	8	<i>BA</i>	8	<i>BA</i>	8	<i>SA</i>	25	<i>BA</i>	30	<i>AS</i>	11

VM = *Vitex madiensis*, *A* = *Acacia seyal*, *BA* = *Balanites aegyptiaca*

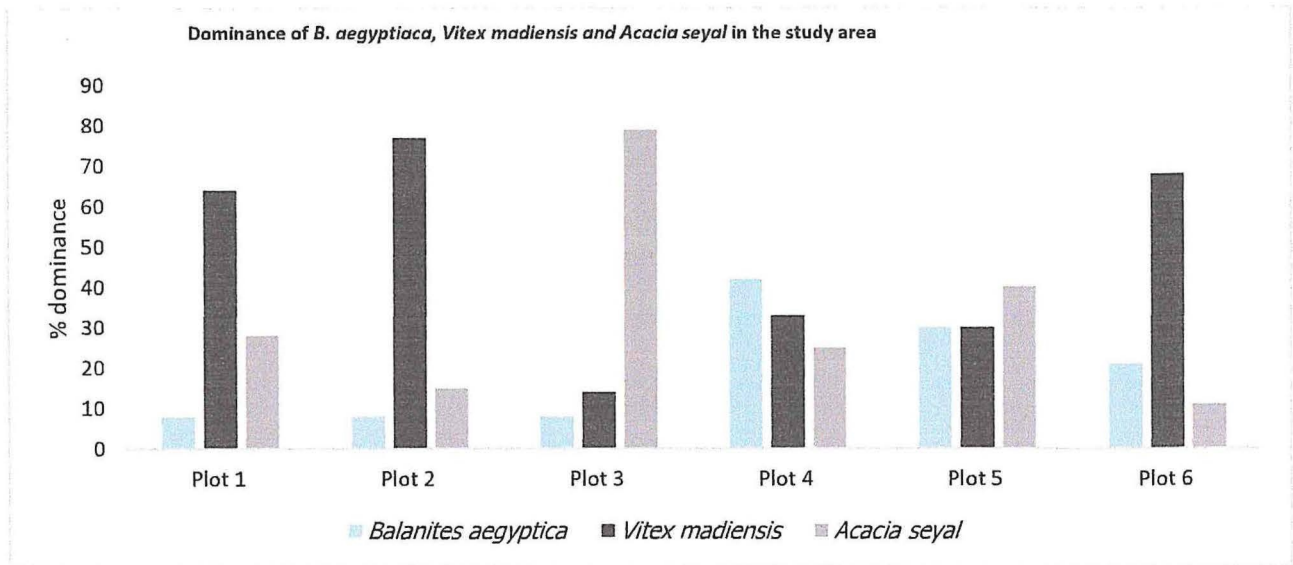


Figure 4.2: Dominance of *Balanites aegyptiaca*, *Vitex madiensis* and *Acacia seyal*

4.1.2 Influence of harvesting on distribution (dbh), abundance and relative dominance

Results from the regression analysis (Table 4.4) showed that there was sufficient evidence that the model fitted the data adequately ($\chi^2 = 8.708$, $d.f = 3$, $p = 0.033$). The results further revealed that relative dominance was a significant predictor for rate of *Balanites aegyptiaca* harvested ($\chi^2 = 19.224$, $d.f = 3$, $p = 0.000$). The rate of harvesting was on average 1.555 times greater for each additional abundant species present. In other words, there was a 55.5% increase in the mean number of trees harvested for each extra abundant species available. On the other hand, there was no evidence suggesting that abundance significantly affected the rate of harvesting trees ($\chi^2 = 0.000$, $d.f = 3$, $p = 0.987$) after adjusting for the effect of dbh and relative dominance. Similarly, diameter at breast height did not have a significant effect on rate of harvesting trees, after accounting for the effect of abundance and relative dominance ($\chi^2 = 0.110$, $d.f = 3$, $p = 0.740$).

Table 4.4: Regression model predicting the rate of tree harvesting based on abundance, relative dominance, and diameter at breast height

Parameter	Coefficient (β)	Std. Error	Hypothesis Test			Exp (β) (Rate ratio)	95% Confidence Interval for Exp (β)	
			Wald χ^2	df	p-value		Lower	Upper
(Intercept)	-0.690	0.3662	3.547	1	0.060	0.502	0.245	1.028
Abundance	-0.001	0.0672	0.000	1	0.987	0.999	0.876	1.140
Diameter at breast height	-0.054	0.1619	0.110	1	0.740	0.948	0.690	1.301
Relative dominance	0.441	0.1007	19.224	1	0.000	1.555	1.276	1.894
Goodness of fit test: Likelihood Ratio $\chi^2 = 8.708$, $df = 3$; Significance (p) = 0.033; No. of obs. (n) = 32								

The estimated regression equation for predicting average number of trees harvested is given by:

$$\log(\hat{\lambda}) = -0.690 - 0.001\text{Abundance} + 0.441\text{Dominance} - 0.054\text{DBH}$$

The descriptive statistics (Table 4.5 below) from the study showed that on average, 1.4 *Balanites aegyptiaca* were harvested from each sampled quadrat in the study area. The average abundance and relative dominance per plot were found to be 2.9 and 2.1 species respectively. Diameter at breast height was estimated to be 0.88 m per sampled plot. There was high variability observed in number of trees harvested and diameter at breast height (CV > 100%) when compared to abundance and relative dominance which exhibited fairly low variation (CV < 100%).

Table 4.5: Descriptive Statistics of rate of tree harvesting based on abundance, relative dominance and diameter at breast height

Variable	Count (n)	Minimum	Maximum	Mean	Std. Deviation	CV (%)
No of trees harvested	32	0	6	1.44	1.865	129.5
Abundance	32	0	10	2.97	1.975	66.5
Diameter at breast height	32	0	3	0.88	1.008	114.5
Relative dominance	32	0	6	2.06	1.366	66.3

CV: Coefficient of Variation

4.2 Utilization, effects of leaf harvesting methods and Land cover Land Use change on regeneration of *Balanites aegyptiaca*

4.2.1 Utilization of *Balanites aegyptiaca* by local communities

The study survey recorded utilization of *Balanites aegyptiaca* by the local community in the study area (Figure 4.3 below). The study recorded 68.6% of the respondents (n=70), agreed that most locals harvest the tree for food as compared to other uses. The number of respondents who believed that *Balanites aegyptiaca* is used for food significantly differed from the ones that believe it is used for medicine, source of income and fuel ($\chi^2=11.5$, $d.f=3$, $p>0.05$).

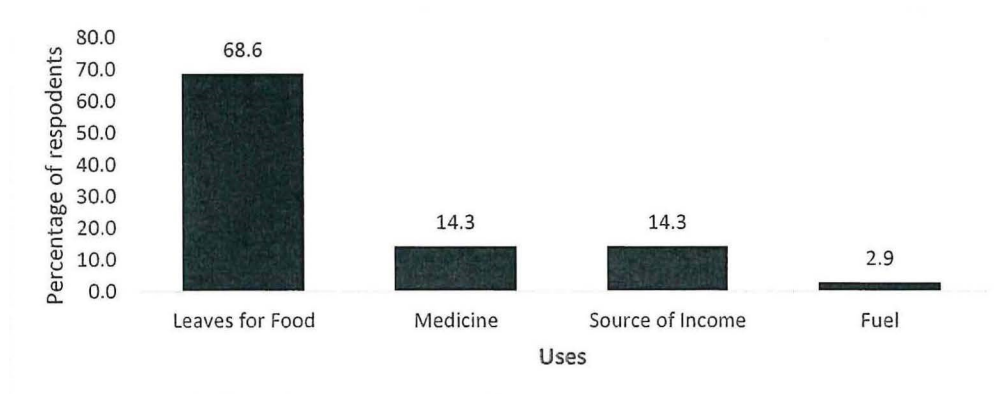


Figure 4.3: The percent utilization of the *Balanites aegyptiaca* by the local communities in Katakwi district

On the other hand, the study find that food and medicine are the most beneficial products from the tree (Table 4.6). According to the respondents (n=70), the leaves of the *Balanites* (73.7%) is the most beneficial part of the tree to the local community since it is the main source of vegetables during dry season.

Table 4.6: Benefits and most beneficial part of *Balanites aegyptiaca* used by the local community

Category	Percent
<i>Benefits</i>	
Medicine	32.4
Food, Fruit and Oil	55.4
Source of Income	8.1
Firewood	2.7
Study Purpose	1.4
<i>Most beneficial part</i>	
Leaves	73.7
Roots	13.2
Seeds	7.9
Bark	5.3

4.2.2 Methods of harvesting and frequently used methods

The study recorded the methods used in harvesting as tree felling, branch lopping, leaf plucking directly from young trees and use of ladder to pluck leaves (Figure 4.4). The study results showed that methods such as tree felling and branch lopping were the most used to harvest the *Balanites aegyptiaca* compared to leaf plucking from the young trees and use of ladder (Table 4.7 below). The total mean number of trees harvested was 11.5₋+6.1. The percentage of trees harvested reduced with the frequency of different method. Methods that require use of tools (1 and 2) such as pangas and axes were more frequently used for harvesting compared to other methods that did not need tools (3 and 4)

Table 4.7: Percentage number of trees harvested per method

No	Method	% no. trees harvested down
1	Tree felling	52
2	Branch lopping	43
3	Leaf plucking directly from young trees	2
4	Use of ladder to harvest	3

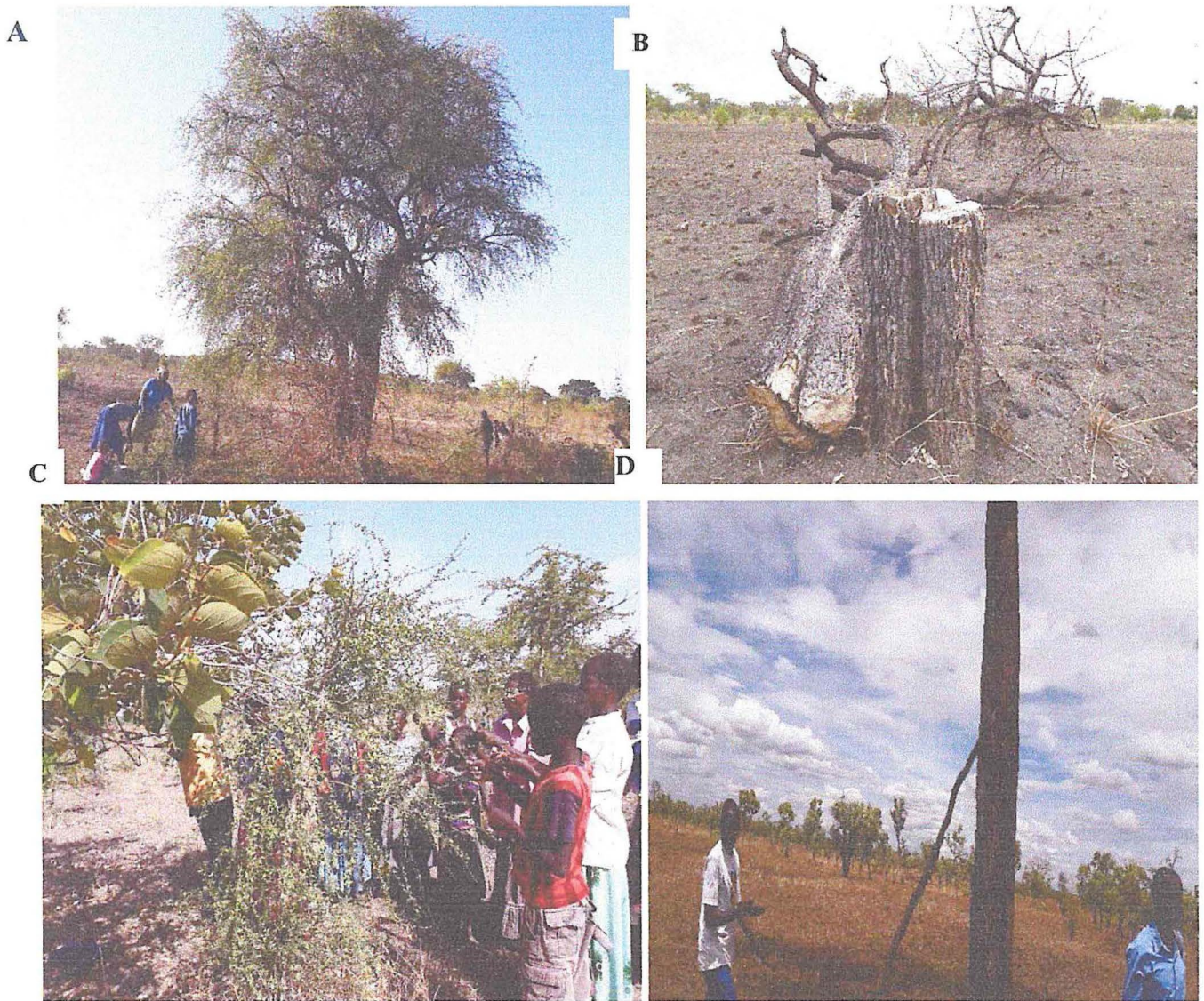


Figure 4.4: Pictures of Methods of harvesting *Balanites aegyptiaca* captured in the field:
A- branch lopping, B– Tree felling, C – Leaf plucking directly from the tree and D – Use of ladder to pluck leaves

4.2.3 Relationship between methods of harvesting and natural regeneration of *Balanites aegyptiaca*

The study determined the relationship between harvesting methods and natural regeneration by using correlation statistical methods. The results indicated that tree felling and branch lopping had a positive strong correlation with regeneration of *Balanites aegyptiaca* (Figure 4.5 below). Tree felling ($r=0.850$, $d.f=5$, $p=0.003$) had a stronger positive relationship with regeneration compared to branch lopping ($r=0.768$, $d.f=5$, $p=0.01$). The results further revealed that leaf plucking directly from the tree ($r=0$, $d.f=5$, $p=0.05$) and use of ladder ($r=0$, $d.f=5$, $p=0.05$) had no correlation with regeneration.

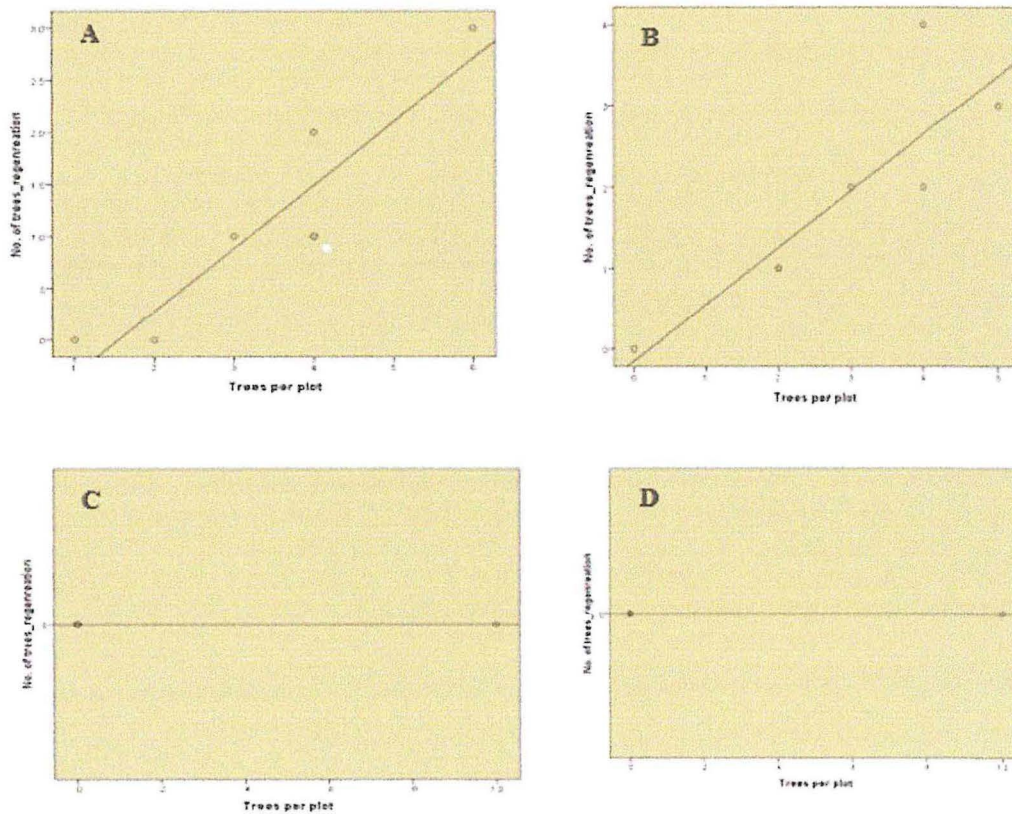


Figure 4.5: Correlation between the methods of harvesting and regeneration of *Balanites aegyptiaca*. A – Tree felling; B – Branch lopping C –Leaf plucking directly from the tree and D- Use of ladder to pluck leaves

4.3 Land cover Land Use change in last 40 years in the study area

The types of land use in the study area ranged from built up areas, grassland, bush land, woodland, subsistence farmland, and wetland cover (Table 4.8 below). The study discovered that in 1979 (Figure 4.6 below), Ngariam sub county was mainly covered by wetlands 93.49 km² (38.74 %) followed by grassland 67.85 km² (28.11%), bush land 51.87 km² (21.49%), subsistence farmland 13.28 km² (5.50%), woodland 11.03 km² (4.57%), and built up areas 3.81 km² (1.58%). The results show that in 2019, subsistence farming 186.71 km² (77.37%) drastically increased in coverage followed by bush land 21.46 km² (8.89%) and grassland 17.73 km² (7.35%), built up areas 9.08 km² (3.76%). Wood land 4.23 km² (1.75%) and wetlands 2.11 km² (0.88%) showed a total decline in land cover.

Meanwhile the study also finds that in Ongongoja Sub County (Figure 8 below), in 1979, wetlands 235.62 km² (46.62 %) were the main land use/land cover followed by bush land 105.43 km² (20.86%), grassland 97.93 km² (19.38 %), subsistence farmland 38.32 km² (7.58%), woodland 25.27 km² (5.09%) and built up areas 2.42 km² (0.48 %). In 2019, the result show that anthropogenic activities such as subsistence farmland 281.31 km² (55.66 %) drastically increased and bush land and grassland declined to 92.64 km² (18.33 %) and 79.36 km² (15.70 %). While woodland 25.04 km² (4.5 %) and wetlands 10.11 km² (2.00 %) are on decline as the built up areas 16.97 (3.36 %) moderately increase.

Table 4.8: Percentage Change of Land cover Land Use change in the last 40 years

LULC	NGARIAM					ONGOGOJ A				
	1979		2019		Change	1979		2019		Change
	Area Km ²	Percentage	Area Km ²	Percentage	Km ²	Area Km ²	Percentage	Area Km ²	Percentage	Km ²
Built Up Areas	3.81	1.58	9.08	3.76	5.27	2.42	0.48	16.97	3.36	14.55
Bushland	51.87	21.49	21.46	8.89	-30.41	105.43	20.86	92.64	18.33	-12.79
Grassland	67.85	28.11	17.73	7.35	-50.11	97.93	19.38	79.36	15.70	-18.57
Subsistence Farmland	13.28	5.50	186.71	77.37	173.42	38.32	7.58	281.31	55.66	242.99
Wetlands	93.49	38.74	2.11	0.88	-91.38	235.62	46.62	10.11	2.00	-225.51
Woodland	11.03	4.57	4.23	1.75	-6.79	25.72	5.09	25.04	4.95	-0.68
Grand Total	241.33	100.00	241.33	100	0.00	505.43	100	505.43	100.00	0.00

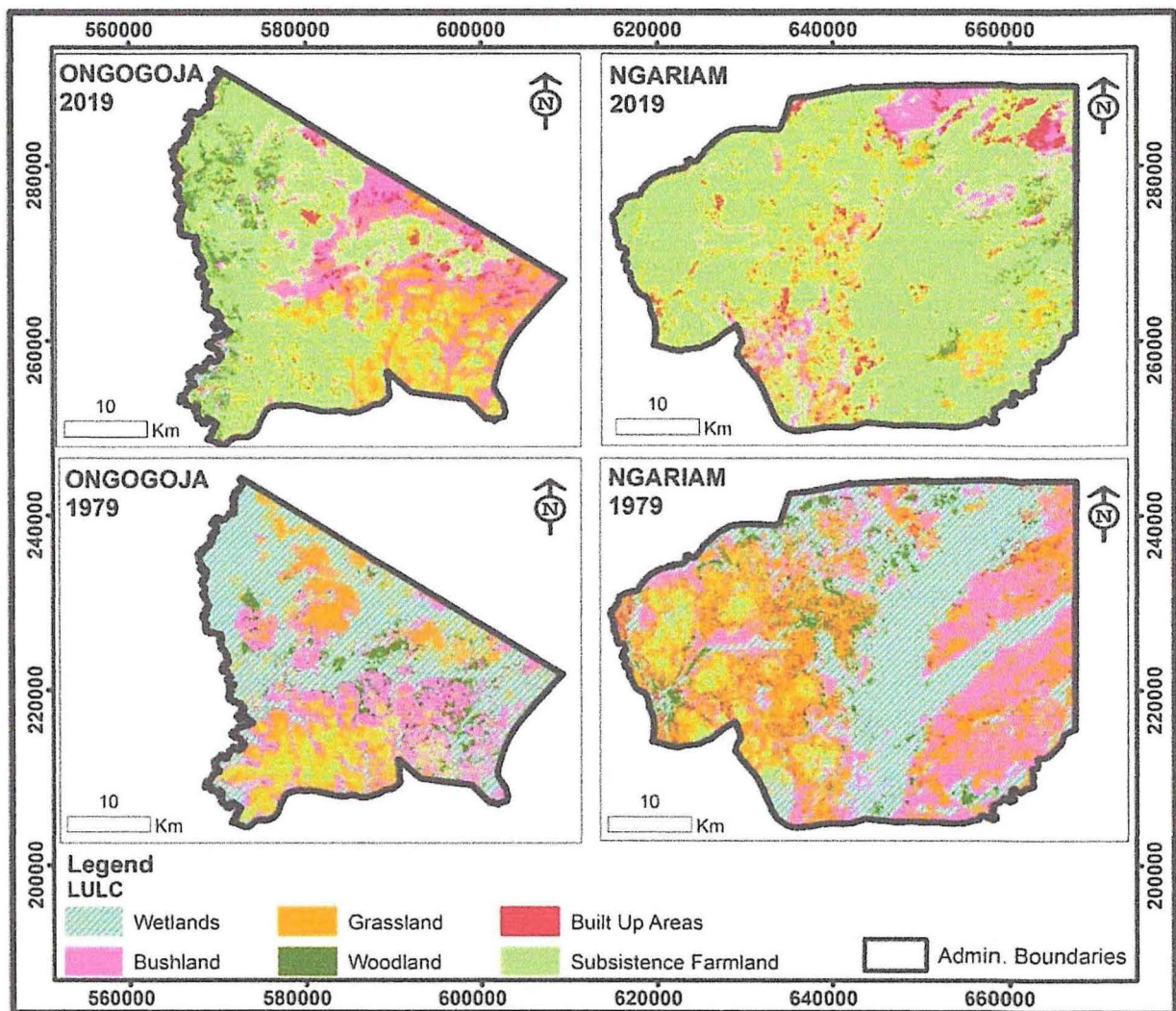


Figure 4.6: Land cover land use change map of Ongongoja and Ngariam sub counties between 1979 and 2019

4.4 *Balanites aegyptiaca* harvested during dry and rain season on daily basis

The study result show that a big number (>80) of *Balanites aegyptiaca* is harvested daily during the dry season and this number decreases (41-60, 21-40, 61-80 and 0-20) as the season transmits to rainy season. On the other hand, small number (41-60, 21-40 and 61-80) of *Balanites aegyptiaca* are harvested during rainy reason and the lowest harvested number mentioned by the respondents

(93.1%) was 0-20 (Figure 4.7 below). The number of *Balanites* harvested during the dry seasons is not significantly different from the ones of rainy season ($\chi^2 = 11.07, d.f=5, P>0.05$).

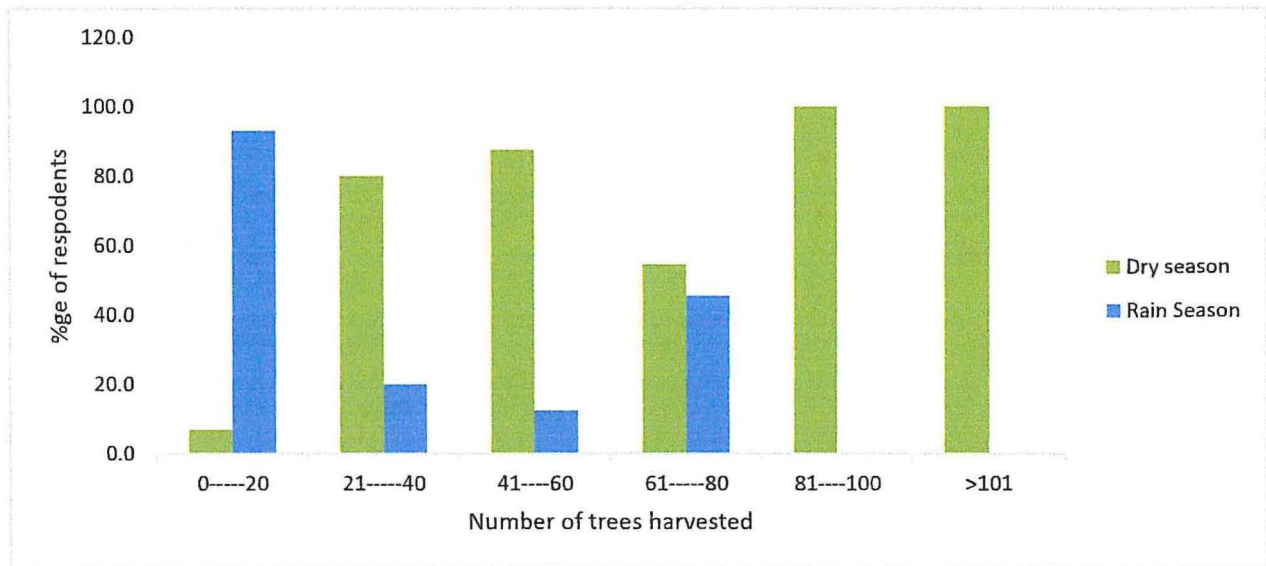


Figure 4.7: Population of *Balanite aegyptiaca* harvested during dry and rain season

4.4.1 Local threats to the population *Balanites aegyptiaca*

The local threats identified by the study included wildfire, livelihood activities (leaf harvesting for food, medicine and income), wood fuel (charcoal and firewood), pest and diseases, timber logging, clearing land for agriculture and others (Figure 4.8 below). The result show that bush fire (59.3.5%), wood fuel (60%) and livelihoods (65.1%) are the main local threats to *Balanites aegyptiaca* in the study while pest and disease (66.7%) and clearing land for agriculture (61.5%) pose limited threat to the tree population. The respondents who agreed that the local threats cause decrease in the population of *Balanites* is not significantly different from those that disagree ($\chi^2 = 11.07, d.f=5, p>0.054$).

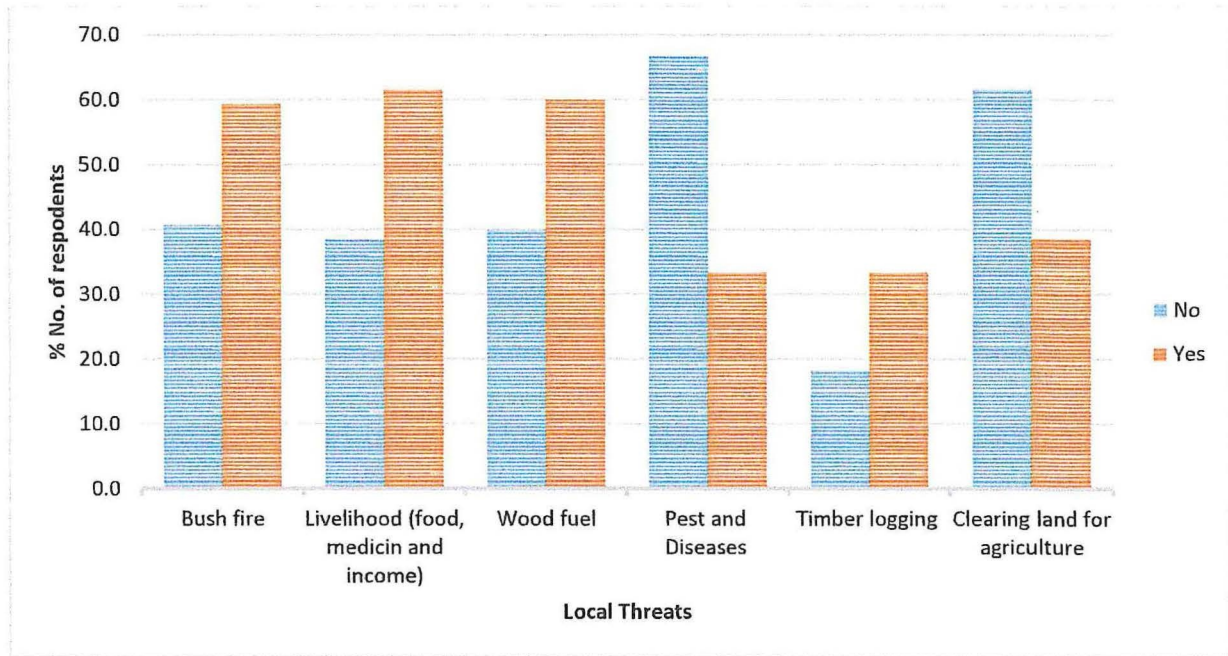


Figure 4. 8: Local threats to *Balanites aegyptiaca* in Katakwi district

4.5 Conservation, Management Options and Socio-Economic Importance of *Balanites aegyptiaca*

4.5.1 Local conservation measures used by community to conserve *Balanites aegyptiaca*

The respondents were asked about the conservation measures community members use to conserve *Balanites aegyptiaca* locally. The survey showed that sensitization to curb deforestation was most common method used followed by clan byelaws, cultural norms, controlled grazing and on farm retention then followed in that order (Figure 4.9 below). Culturally based measures such as cultural norms, enforcement of clan byelaws and sensitization on dangers of deforestation were the most preferred methods while community base methods (controlled grazing and farm retention) were less favored methods used to conserve the species.

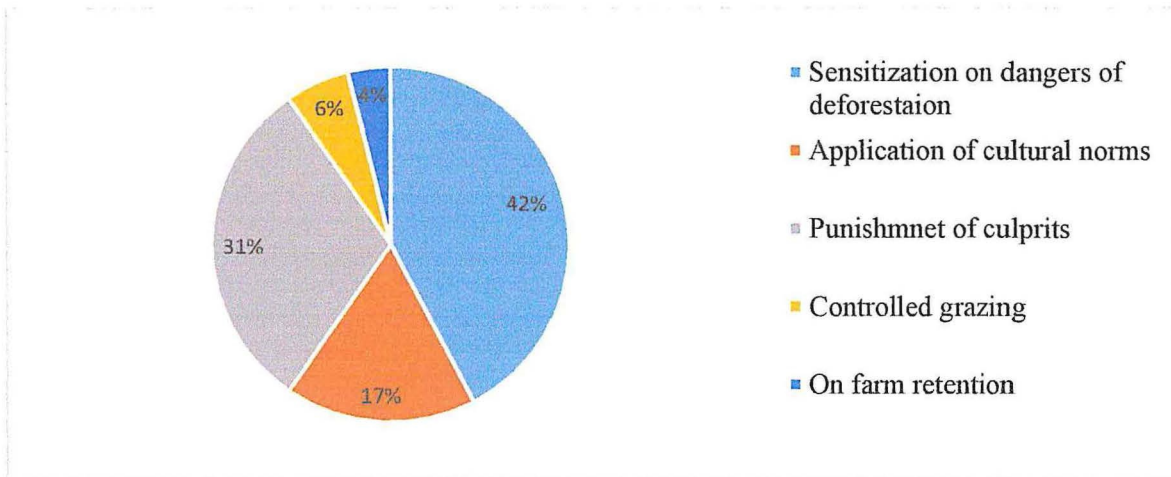


Figure 4.9: Community suggested interventions to conserve the *Balanites aegyptiaca*

4.5.2 Management options and Institutional involvement used by the local community to conserve *Balanites aegyptiaca*

The survey recorded several management options from the respondents during the study survey. They included enforcement of policies and regulations by government entities, enforcement of the traditional byelaws such as disciplining the culprits, fining offenders among others and traditional practices such as on farm retention, grazing around the tree, controlled burning and farming (Table 4.9). However, enforcement of policies and regulations by government authorities such as Local Government, National Forestry Authority, National Environment Authority, Uganda Wildlife Authority was most mentioned management option by the respondents followed by enforcement of Traditional bylaws and Traditional practices was least mentioned. The respondents reported the institutions involved in management of the *Balanites* included Elders council/Traditional Leaders, National Forest Authority (NFGA), National Environment Management Authority (NEMA), District, Sub County and other institutions. The survey result show that Elders council/Traditional Leaders (29.9%) and sub County (23%) are more involved in management of the tree compared to the rest of the institutions.

Table 4.9: Institutional involvement and Management options to conserve *Balanites aegyptiaca*

Category	Percentage
<i>Management Options</i>	
Enforcement of law by Government Entities	55.2
Enforcement of traditional bye laws	29.9
Traditional Practices	14.9
<i>Institutions involved in management</i>	
Elders council/Local leadership	29.9
NFA	12.6
MWE	8.0
District	17.2
Sub County	23.0
Others	9.2

CHAPTER FIVE

DISCUSSIONS

5.1 Distribution of *Balanites aegyptiaca* in Katakwi district

The result showed that, the study area was sparsely distributed with mature *Balanites aegyptiaca* (large diameter at breast height - dbh). This could be attributed to high mortality rate taking place at seedling and sapling level due to both human and natural factors as bush burning, goat browsing, cutting of the sapling for poles and among others. Like this finding was a finding by Okia , (2010) who found that most of the *Balanites aegyptiaca* in Katakwi district had large diameter at breast height and were at their old age. This could also be as a result of local community reserving the mature trees for their own benefits. Sagna , Niang, Guisse, & Goffner, (2014), reported high consumption of fruit and wood parts by local people in Senegal. There were fewer young (saplings) and very older trees in the study area and this could be attributed to factors such as bushfire that destroys the seeds and seedlings, pest and diseases, browsing ruminants among others. In addition, the Focus Group Discussions attributed the fewer numbers to the old trees dying off because of loss of vigour since the trees were over harvest seasonally Contrary to this report, Yougouda, Dorothy, Michel, & Marie, (2018) reported high distribution of young *Balanites aegyptiaca* in West Africa. This could be due to different socio-economic activities associated with the utilization of the *Balanites aegyptiaca* and other environment factors that vary.

Abundance of *Balanites aegyptiaca* and its associated tree species (*Vitex madiensis* and *Acacia seyal*) in Katakwi district

The study recorded high abundance of *Vitex madiensis*, followed by *Acacia seyal* and *Balanites aegyptiaca*. The low abundance of *Balanites aegyptiaca* was associated with over harvesting by the local community due to a unique function (provision of food) it provides compared to *Vitex*

mediensis and *Acaci seyal*. The finding is similar to (Okia , 2010) who reported low abundance of *Balanites aegyptiaca* in Katakwi district as compared to what he recorded in Adjumani district. Even though the abundance of *Balanites aegyptiaca* recorded low among the species studied, high abundance was recorded in some plots. This might be attributed to different environmental and social economic factors affecting the species. For example, the FGDs in Ngariam Sub County recorded that, the local community preferred to fell the species for charcoal while in Ongongoja Sub County, the local community spared the tree for vegetable leaves. Contrary to this report, Sagna , Niang, Guisse, & Goffner, (2014) reported high abundance of *Balanites* in Sahelian zone of Senegal, a region with similar climatic conditions to the Katakwi district. The differences in the findings can be attributed to the two different communities utilize *Balanites aegyptiaca*.

The study result revealed that relative dominance was a significant predictor for rate of *Balanites aegyptiaca* harvested. The number of *Balanites aegyptiaca* harvested was more influenced by relative dominance than abundance and DBH. This could be because the dominant species is more likely to be utilized/harvested compared to the scarce ones. Contrary to this study, Van der Sande, et al., (2020), reported non-significant relationship between abundance and human influence on trees due to a weaker relationship between human influence and propagule pressure.

The results of this study indicated 55.5% of *Balanites aegyptiaca* were harvested every time there is increase in the relative dominance. This could be because the local communities associate the more number of the trees in area with availability of the trees and hence they harvested more of it. Ortiz , et al., (2019), identified factors such as deforestation, fragmentation, overgrazing, fire, conversion to agriculture, and drought responsible for loss of species however, he reported that these factors can also increase the abundance of other species.

5.2 Utilization, effects of leaf harvesting and Land cover Land Use change on the regeneration of *Balanites aegyptiaca*

Indigenous Fruit Trees (IFTs) are utilized by communities for various purposes and these include food security, income, medicine, cultural and other related purposes (De Leeuw, Njenga, Wagner, & Iiyama, 2014). The study established that *Balanites aegyptiaca* is in most cases utilized as food in Katakwi district. This is because it has been used as vegetable to provide sauce during dry season for the local communities for long period. Elfeel & Warrag, (2011), (Valvi & Rathod, 2011) reported that *Balanites aegyptiaca* can serve as a safety net for the communities that eat it especially when food become scarce. Understanding such utilization is very important in planning and management of the resource. Other studies have argued that Indigenous Fruit Trees (IFT) such as *Balanites aegyptiaca* may not only be important as food but also serve other several roles for the communities though the circumstance depends (Motlhanka, Motlhanka, & Selebatso, 2008; Tabuti & Mugula, (2007). Significant number of respondents agreed that *Balanites aegyptiaca* is a very useful tree species in Katakwi district. However, their harvesting methods (cutting off branches and cutting off the tree) especially during the flowering and fruiting exposed *Balanites aegyptiaca* to degradation and this was not sustainable for the existence of the tree because it reduces the tree productivity and stop the chance of succession. Kidane, Van der Maesen, van Andel, Asfaw, & Sosef, (2014) reported that due to the diverse uses of IFTs, they may be exposed to overexploitation or otherwise threatened especially in periods of food scarcity. Even though the *Balanites aegyptiaca* is widely utilized in Katakwi district, its potential is not fully exploited in areas of medicine, agroforestry, marketability among others. Katende, Birnie, & Tengnäs, (1995) reported limited attention and underutilization of *Balanites aegyptiaca* in Uganda.

The study recorded benefits such as food, medicine, firewood, source of income and study purpose. However, food and medicine are the most beneficial products the community enjoy because of their direct benefit the community gets and are utilized in times of hardship such as dry season when food is scarce and sickness. In a related study, Okafor, (1988) reported that indigenous fruits such as *Balanites aegyptiaca* contribute significantly to diets of rural households as they have high nutritional value and are rich in vitamins and minerals. Agea, Obua, Kaboggoza, & Waiswa, (2007), reported similar benefits such as treating convulsions, abdominal pain and diarrhoea. Chevalier *et al.*, (2003) reported that *Balanites aegyptiaca* has been cited in veterinary medicine in Burkina Faso.

The study recorded the methods used in harvesting *Balanites aegyptiaca* leaves as cutting down the tree, cutting off the branches, climbing to harvest from the crown and hand picking directly from the ground. The methods offered different ways of harvesting, and each was used differently from each other by the community members. The results showed that most of the participants agreed using these methods because they provided easy way of plucking the leaves with reduced chances of getting accident. This is in relationship with Leakey, et al., (2009) who documented baobab leaves harvested using similar methods in Ghana for marketing. Similar to this study, Guinko & Pasgo, (1992) reported harvesting and consumption of young leaves and flowers of *Balanites aegyptiaca* in Burkina Faso for food. Another observation of this study noted that the most harmless methods of harvesting (climbing to pick from the crown and leaf plucking directly from the ground) were the least used methods as compared to the harmful methods (cutting off the branches and felling down the tree). This was also observed in Katakwi district by Okia , (2010) where the community prefer destructive methods of harvesting because of its easy to use, time saving and accidents reduction advantages. In related study, Okia , (2010) reported that using

ladder was noted to pose a serious problem to harvesters and cases of accidents, though rare, were reported and might be reason why the method is not commonly used. Given the trend, one can say that, if destructive methods are not well managed, it can cause an overall decrease in number of the tree.

The study recorded a change in the land cover land use of the study area in last forty years (1979 - 2019). Land cover land uses such as subsistence farming, built up areas are reported to be on increase while land cover land use such as bush land, wood land, wetlands were recorded to be on decline due to increased human activities such as farming, construction, settlement and other natural factors such as climate change that might affect the resources. Similar to this study, Akello, Turyahabwe, Okullo, & Agea, (2016), reported increased change in built up areas and open waters in the sub region in the period of 2007 to 2013. In agreement to this study, (Majaliwa, *et al.*, 2018) noted that despite an increment in commercial agricultural land, subsistence agricultural land remains the most dominant land use system across the country. It is also worthwhile to note that the areas under bush land with moderate livestock activities, unprotected bush land, grassland with low livestock activities, grassland with moderate livestock activities, encroached tropical forest, and woodland which is unprotected or with livestock activities declined by 2015 (Majaliwa, *et al.*, 2018). The results further showed that most of the respondents agreed that there was a reduction in number of *Balanites aegyptiaca* per acre of land. The study recorded fewer *Balanites aegyptiaca* in an acre in 2019 compared to 1979. This differs from (Madrama, 2006) who reported higher *Balanites* stocking levels in West Nile, a region that also highly rely on the same tree. The few number of *Balanites aegyptiaca* recoded to date can be associated with both natural and human factors such as old age, pest and diseases, flooding, logging, charcoal burning, agricultural land opening, weak policies among others. Adebooye & Opabode, (2004) reported that in sites where

there is periodic flooding, *Balanites aegyptiaca* trees tend to be scantily distributed though tends to be densely populated in riparian sites.

The results showed that few *Balanites aegyptiaca* are harvested daily during rainy season while more *Balanites* are harvested in the dry season. During the rainy season, the communities are presented with different sources of vegetable and hence they do not seek for *Balanites aegyptiaca* as source of vegetable. Agea, Obua, Kaboggoza, & Waiswa, (2007) reported that families depend on indigenous fruit trees such as *Balanites aegyptiaca* during times of food shortage and that indigenous fruit trees are a good source of income. Barnett, (2001), reported that when there is sufficient food from normal crop harvests, the use of wild foods is ignored and people who eat them are considered "inferior".

The study recorded local threats to *Balanites aegyptiaca* as wildfire, livelihood activities (harvesting the leaves for vegetables, medicine and income), wood fuel (charcoal and firewood), pest and diseases, timber logging and clearing land for agriculture. Most participants reported that wild fire, wood fuel and clearing land for agriculture are the main local threats to *Balanites*. Elfeel & Warrag, (2011) reported related causes to deterioration of tree such as mechanized cropping, selective cutting for furniture industry, over grazing and lopping of branches for browsing and gap in transfer of local knowledge between generations. The use of these materials and charcoal from *Balanites aegyptiaca* has also been reported by women in Burkina Faso (UNDP, 2009). Webb, Cushing, & Wright, (1984) reported a calorific value of 4600 kcal per kg of *Balanites aegyptiaca*.

5.3 Conservation, Management and Socio-Economic Importance of *Balanites aegyptiaca*

Results from the social economic survey recorded that the local conservation measures included; sensitization, cultural norms, clan byelaws, controlled grazing and on farm retention do exist

because the measures are part of their clan system. Similar to this report, (Okia , 2010) found that locals in Katakwi district were able to plant or retain *Balanites aegyptiaca* near home or scattered on- farm or along farm boundaries.

Amongst other findings included; management options and institution involvement in management of *Balanites aegyptiaca*. The results show that management options such as policy enforcement, traditional byelaws, fining offenders, farm retention and controlled burning do exist in the management framework of the local community. The overwhelmingly management option and diverse involvement of different institutions could protect the tree from extinction and promote its conservation. Okullo, Hall , & Obua, (2004), argued that local management options could raise the status of *Balanites aegyptiaca* leading to its protection as it has already happened with *V. Paradoxa*.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study found that the distribution of *Balanites aegyptiaca* is dominated by trees that have large diameter at breast height an indication of mature/old trees in the study area. The study results showed low abundance of mature *Balanites aegyptiaca* as compared *Vitex madiensis* and *Vitex madiensis* during the study. The study discovered that the local communities utilized *Balanite aegyptiaca* for food, income generation, medicine among others and methods of harvesting included branch lopping, tree felling, leaf plucking from young trees and use of ladder to pluck from the crown. The land cover land use over the years revealed reducing area for forest and woodlands mainly due to increasing conversion of natural land to agricultural land. It was also realized that local conservation measures such as controlled grazing, on farm retention, clan byelaws, sensitization and cultural norms were used by the communities to encourage conservation, but government policy enforcement were not often mentioned meaning its implementation is lacking.

6.2 Recommendations

The following are recommendations both general and for future studies based on the results and conclusions of this study

1. The community needs to be supported to promote *Balanites aegyptiaca* into farming systems as agroforestry tree to sustain the resource base through a collaborative plan between the communities and government agencies such as District Forest Office and National Forestry Authority.

2. The less harmful methods of harvesting *Balanites aegyptiaca* leaves such as picking the leaves directly from the tree need to be promoted in the study area to encourage sustainable utilization of the tree.
3. Domestication of the *Balanites aegyptiaca* tree by the local communities should be promoted. The tree has the potential to grow domestically and provide large scale benefits both locally and on industrial scale.
4. Alternative sources of livelihood need to be sought for the communities to reduce the pressure on the tree especially during the dry seasons

Recommendation for further studies

1. The *Balanites aegyptiaca* distribution along moisture gradient of the landscape should be studied. This may offer an opportunity to restore degraded wetlands especially in Teso sub region since the tree was found to be lying along both dry and moist gradient of the landscape.
2. A detailed study to assess its genetic diversity is needed to ascertain which sub species is more threatened in order to prioritise conservation efforts. Not all the sub species are utilized for the same purpose and hence a genetic erosion is taking place in one or two sub species more than others.
3. A social economic survey is needed to find why the community in Ngariam Sub County prefer to use *Balanites aegyptiaca* tree for wood fuel and buy the leaves from neighbouring districts while the communities in the Ongongoja sub county prefer to use the tree as a vegetable.

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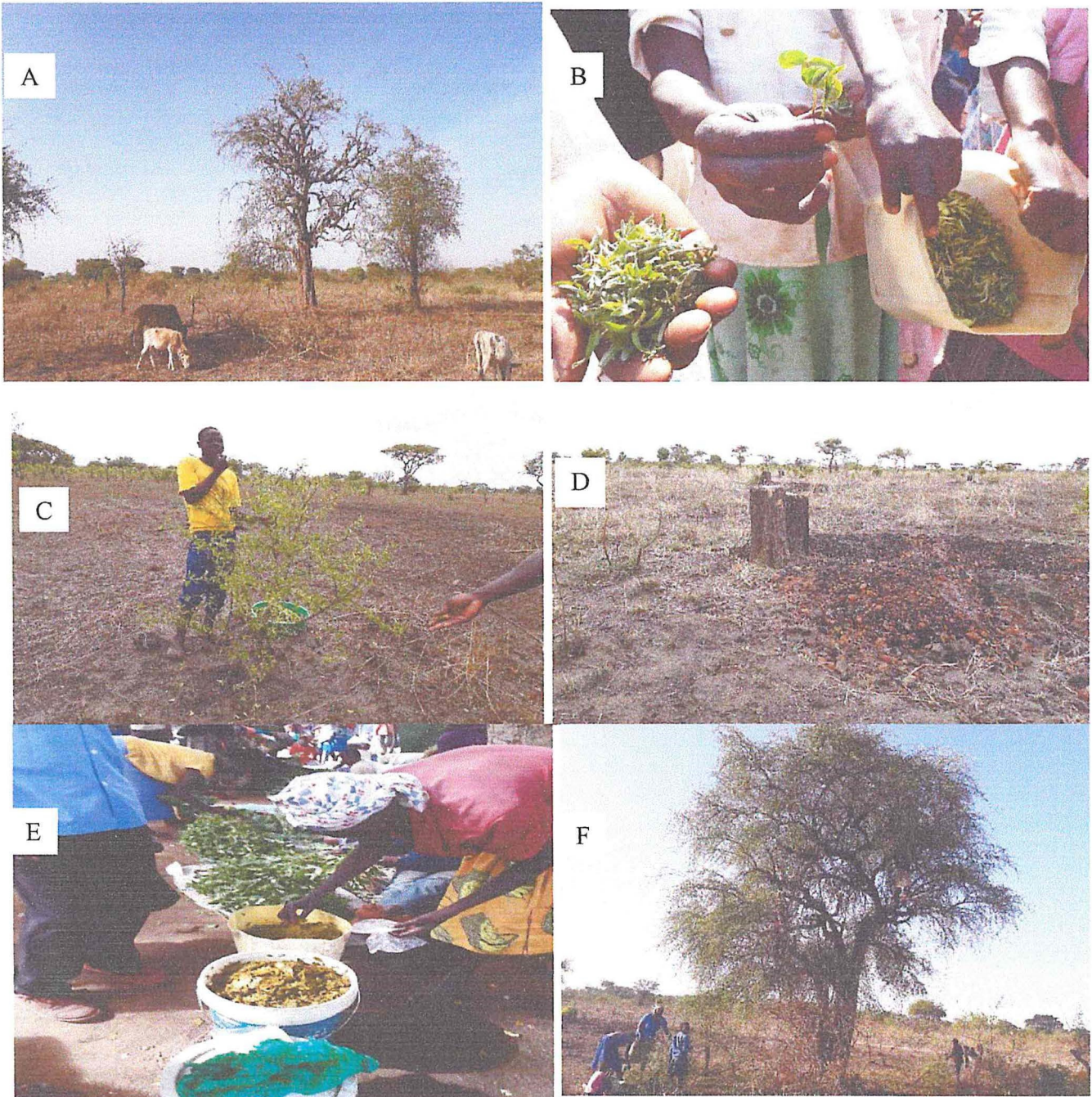
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APPENDICES
APPENDIX 1: PHOTO GALLERY



Pictorial: A-Cattle browsing on unpicked leaves on the branches, B – Community members displaying an alternative vegetable they harvested instead of Balanites leaves, C– Community Member piking leaves from a branch that has been cut, D-A stump of Balanite

APPENDIX 2: FIELD PROTOCOL

Material and Equipment

1. 100m ropes
2. Nails
3. 30M graduated tape measure
4. Quadrat frame of at least 1x1m
5. 4 wooden pegs
6. Books
7. Pens
8. Gumboots
9. Gloves

Procedure

- a) Set an area using the 4 pegs measuring 100x100M in a fairly grown area with *B. aegyptiaca*
- b) Run the rope around the 4 pegs to form a plot of 100x100M square
- c) Do not remove the rope from the pegs
- d) Consider the 100mx100m as your first plot
- e) Lay quadrats of 10mx10m at random inside the plot and count how many mature *B. aegyptiaca* tree measuring ≥ 10 cm (DBH) inside the quadrat
- f) Lay quadrats of 5mx5m at random inside the quadrat above and count how many saplings (measuring ≤ 5 cm DBH or less than 1.5 m height) are inside the quadrat.
- g) Lay quadrats of 1mx1m at random inside the quadrat above and count how many seedling (measuring < 1 cm) are inside the quadrat
- h) Repeat procedure the above for the subsequent sites

Table 1: Recording sheet

Plots Number	Number of individuals	Diameter at Breast Height (DBH)	Height	Comments
1				
2				
3				
4				
5				

APPENDIX 3: RESEARCH QUESTIONNAIRE

As one of the partial requirements for the completion of my master course in Conservation and Natural Resources of Kyambogo University, am conducting a research titled “Conservation of *Balanites aegyptiaca* as an adaptation indigenous fruit tree for semi-arid communities in Teso Sub Region (Katakwi District)”. You have been selected as one of the respondents to provide information for this research and this information obtained is strictly used for research purpose and will be treated with utmost confidentiality.

Title of respondent.....

District: _____ SubCounty _____ Parish _____

Village _____ Date _____

SECTION A: BACKGROUND INFORMATION (Tick as appropriate)

1. Age

(i) 20-----29 (ii) 30----39 (iii) 40----49 (iv) 50----59 (v) 60≤

2. Gender (Tick one)

(i) Male _____ (ii) Female _____

3. Highest Level of Education (tick one)

(i) Certificate _____ (ii) Diploma _____ (iii) Bachelors _____ (iv) Masters _____ (iv)

Others (If so Specify) _____

4. How long have you served in this Ministry/District/sub county/Village (tick one)?

(i) 1---5 years (ii) 6-----10 years (iii) 11---15 years (iv) 16---20 years (v) 21-----25 years (iv)

>25.....

SECTION B: METHODS OF HARVESTING (TICK AS APPROPRIATE)

1. What are the major indigenous fruit trees in the area (Katakwi district)?

.....

2. What are the **types** of method being used by community members to harvest parts of *B.aegyptiaca (ecomai)* tick the in the boxes?

Code	Method	Yes	No
1	Cutting only twigs/branches		
2	Hand picking the leaves		
3	Felling down the tree so that leaves can be picked		
4	Using ladders to pick the leaves		
5	Other (specify)		

2. Which method is most used by the communities? Use 1-5 (1-most used and 5-least used)

Code	Method	Numbers
1	Cutting using pangas, hoes, axes	
2	Hand picking soft leaves	
3	Felling down the tree so that leaves can be picked	
4	Climbing ladders to pick the leaves	
5	Other (specify)	

Do these methods allow generation of the tree?

Yes

No

If yes explain

.....

4. Does the methods affect the natural generation of the *B. aegyptiaca*? Please tick one

Yes

No

3. How are these methods being used? (describe)

.....
.....

5. How does it affect the regeneration of the *B.aegyptiaca*? **describe**

.....
.....

6. What type of tools are being used to cut branches and leaves of *B. aegyptiaca*?

1.

2. Others

7. List varieties/types of *B. aegyptiaca*

I.

II.

8. Which variety/type of *B. aegyptiaca* is mostly harvested by communities? List according to the order

1.

2.

9. Which type is most eaten (according to the order of consumption)

1)

2)

1.0 What are the local threats to the *B. aegyptiaca*?

1.

SECTION C: CONSERVATION AND MANAGEMENT OPTIONS

1. What management options do exist to conserve the tree?

a.

2. How are you maintaining the survival of the tree?

a)

b) Others

3. Who is responsible for the conservation of the tree?

1. Ministry of Water and Environment

2. NFA

3. District

4. Sub county

5. Community

6. Others

4. What are you doing now to conserve the tree?

1.

2.

3. Others

6. Is this tree recognized by government like any other indigenous fruit tree for example shear butter?

Yes

No

7. If so, what is government doing to conserve the tree?

.....
.....

8. What is the attitude of the community towards conservation and protection of the tree according to your experience?

.....

9. What do you think can be done to conserve the tree?

.....
.....

SECTION D: IDENTIFICATION, DISTRIBUTION, ABUNDANCE AND NATURAL REGENERATION

1. What are the varieties of *B. aegyptiaca* you know?

- 1.....
- 2.....

2. What was the number of the trees in an acre about 40 years ago according to your experience?

- 0-20
- 21-40
- 41-60
- 61-80
- >81

3. What is the coverage of the tree in an acre as per now?

- 0 -20
- 21-40
- 41-60
- 61-80
- >81

4. Is there decrease in population of the tree?

- Yes
- No

5. If yes, what are causes? *Write number in the box according to the level of intensity (1-5, 1 high and 5Low)*

- 1. Harvested for leaves, barks, roots for food, medicine, traditional use among others
- 2. Clearing land for agriculture
- 3. Firewood and charcoal burning
- 4. Timber logging
- 5. Others

6. According to your own experience, do you think there is natural regeneration of this tree?

.....
.....

7. To what extent is the natural regeneration of this tree is taking place? (1High -5Low)

- 1 2 3 4 5

8. Give reason for your answer

.....
.....

SECTION E: UTILIZATION

1. Why is the community adapted to this tree?

.....
.....

2. How is the tree being utilized in your community?

.....
.....

3. Which part is most utilized and why?

.....
.....

4. What is the impact of the each of the use you have mentioned above on the tree regeneration?

.....
.....

5. What benefits do you get from the tree?

.....
.....

What is the perception of the community on the tree in regards to its conservation?

.....
.....

SECTION F: SOCIO-ECONOMIC EFFECT

1. How many *B. aegyptiaca* trees do you think are being harvested during the drought season by the communities?

0-20 21-40 41-60 61-80 81-100 >101

2. How many trees do you think are being harvested during rainy season by the communities?

0-20 21-40 41-60 >61

3. How many households do you think can be involved in massive harvesting during the drought?

0-20 21-40 41-60 61-80 81-100 >10

4. Are the seeds of this tree also useful to this community?

Yes No

5. If yes, how useful are they? *List them*

- 1.
- 2.
- 3.
- 4.

6. How are the seeds collected?

.....
.....

Thanks for your time and participation

APPENDIX 4: FOCUS GROUP GUIDE—VILLAGE COMMUNITY MEETINGS

SubCounty _____ Parish _____ Village _____

Date _____

1. Regrowth, Regeneration and Methods

- What preparations are involved in harvesting?
- What type of tools do you use to cut branches and leaves of ecomai for vegetable?
- Which methods are being used to harvest the parts of the tree?
- Do these methods allow regrowth/regeneration of the?
- Which other part of the tree do you harvest and for what purposes?
- Why do burn the bush?
- Do you understand that fire burns ecomai and it can die?
- Do you control the bush burning?
- Who is involved in harvesting the vegetable?
- Do animals (both domestic and wild) eat this young leaf of the tree?
- Do they affect the growth of the tree?
- How do you control goats from eating the leaves of the young tree?

2. Socio-Economic, Conservation and Management

- For how long have you been using echomai as food?
- How has ecomai sustained your lives?
- How important is ecomai to your community?
- How are you maintaining the survival of the tree?
- What are the challenges faced in conserving the tree?

- Which traditional knowledge have been used to conserve the species?
- Which measure are currently in place to conserve the tree?
- What do you think can be done to conserve the tree?
- How often are these measures used?
- Which challenges are being faced in using the measures?
- Do you leave the tree in the garden when clearing land for agriculture?
- Is there any one responsible for managing this tree species? If yes
- Who are they and what is their reasonability?
- Are there other trees to replace ecomai if it gets extinct?

3. Identification, distribution, abundance and natural regeneration

- How many types of ecomai do you know?
- Which type of ecomai do you eat most?
- How often do you harvest the parts of ecomai?
- How many times do you harvest the parts in a day when the need is high?
- How many families do you think entirely rely on the tree during hard times (drought) and why?
- How many families do you think entirely rely on the tree all times and why?
- How many tree species do you think are harvested per day for food?
- According to your experience, do you normally see the young trees coming up to replace the old ones?
- Do you think their number is sufficient enough to replace the old one?
- If No, why?

- Are the old trees still available?
- If No, why and what is causing them to die?
- Which growth stage of the tree parts do you prefer most to harvest your vegetables from?
- Why do you prefer that stage of the tree?
- What is the average distance you used to walk to harvest parts of echomai 40-30 years ago?
- What is the average distance you can walk now to harvest parts of echomai?
- What threats have you seen that are reducing number of the tree?
- Is the number of echomai trees increasing or decreasing?

APPENDIX 5: OBSERVATION CHECKLIST

During the observation exercise, the researcher will be interested to in local community conservation measures, how the tree is regenerating after been cut, dangers to the tree that can only be observed such as goat browsing, children picking the seeds, people feeling the tree and so on and understand the intensity of the destruction. The researcher will note number of the some of the parameters listed below encountered and the name of the place on a note book, including other issues that will be observed. He will be required to take coordinates and pictures of places.

District: ___ Sub County _____ Parish _____ Date _____

Parameters to observe	Yes	No	How many in the plot	Comments (Name of sub county and village, intensity, causes, any measure/initiative)
Tree stumps				
Drying trees				
Tree showing no signs of recovery after leaves are cut off				
Goats browsing on the sapling				
Seedling germinating				
Healthy saplings growing without disturbance				
Trees left in garden				
Trees seeming to be protected by communities				
Burnt trees				
Sprouting trees from burnt damaged				
Sprouting trees from cut part				

APPENDIX 6: SAMPLING FRAMEWORK

#	Target respondents	Rationale	Approach/method /Tool	Population (N)	Sample (S)	Sampling method
1	Sub-county leaders (SAS, CDO, Extension staff—2)	<ul style="list-style-type: none"> • Implementers of policies, informers, 	<ul style="list-style-type: none"> • Questionnaire 	<ul style="list-style-type: none"> • 8 	<ul style="list-style-type: none"> • 8 	<ul style="list-style-type: none"> • Purposive
2	District leaders (forest officer, ranger, Natural Resources Officer, Production officer)	<ul style="list-style-type: none"> • Implementers of policies, informers, planners 	<ul style="list-style-type: none"> • Questionnaire 	<ul style="list-style-type: none"> • 4 	<ul style="list-style-type: none"> • 4 	<ul style="list-style-type: none"> • Purposive
3	Community members (opinion leaders, elders, traditional leaders and others)	<ul style="list-style-type: none"> • Users, indigenous knowledge, social economic effect 	<ul style="list-style-type: none"> • Questionnaires 	<ul style="list-style-type: none"> • 50 	<ul style="list-style-type: none"> • 44 	<ul style="list-style-type: none"> • Purposive
4	National (NFA, MWE- Forestry sector, NaFORRI)	<ul style="list-style-type: none"> • Policy formulators and implementers, breeders, financial allocation, conservationists 	<ul style="list-style-type: none"> • Questionnaires 	<ul style="list-style-type: none"> • 14 	<ul style="list-style-type: none"> • 10 	<ul style="list-style-type: none"> • Purposive
5	Communities (elders, women, girls, opinion leaders)	<ul style="list-style-type: none"> • Users, indigenous knowledge, social economic effect 	<ul style="list-style-type: none"> • FGD and interviews 	<ul style="list-style-type: none"> • 6 	<ul style="list-style-type: none"> • 6 	<ul style="list-style-type: none"> • Random sampling
6	Sub counties	<ul style="list-style-type: none"> • Availability of <i>Balanites aegyptiaca</i> 	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> • 2 	<ul style="list-style-type: none"> • 2 	<ul style="list-style-type: none"> • Purposive
6	Villages	<ul style="list-style-type: none"> • Availability of <i>Balanites aegyptiaca</i> 	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> • 6 	<ul style="list-style-type: none"> • 6 	<ul style="list-style-type: none"> • Purposive

APPENDIX 7: KREJCIE AND MORGAN (1970) TABULATION

<i>N</i>	<i>S</i>	<i>N</i>	<i>S</i>	<i>N</i>	<i>S</i>
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	100000	384

Note.—*N* is population size. *S* is sample size.

Source: Krejcie & Morgan, 1970

APPENDIX 8

A. Abundance data

Balanites aegyptica	Vitex madiensis	Acacia seyal	
	9	72	32
	20	197	39
	12	21	122
	5	4	3
	3	3	4
	6	19	3

B. Distribution data

DBH	Oku pop (100*100m)	Anya pop (100*100m)	Ako pop (100*100m)	Tur pop (100*100m)	Bis pop (100*100m)	Pakwi pop (100*100m)
10-19	0	0	0	2	0	0
20-29	0	0	0	0	0	1
30-39	1	0	1	0	0	0
40-49	0	0	0	0	0	1
50-59	2	3	1	2	1	0
60-69	1	1	3	3	2	3
70-79	1	0	2	1	2	0

C. \$*/rt & Utilization

Uses of Balanite aegyptiaca		
Uses	Frequency	Percent
Leaves for Food	24	68.6
Medicine	5	14.3
Source of Income	5	14.3
Fuel	1	2.9
Total	35	100.0

D. Method harvesting

Methods	Yes	No
Cutting off branches	45.8	29.4
Hand picking from the ground	42.2	24.5
Cutting down the tree	2.4	25.9
Climbing to harvest from the crown	9.6	20.3

E. Local threats

Local Threats	No	% pop	Yes	No	Yes
Bush fire	24	40.7	35	40.7	59.3
Livelihood (food, medicin and income)	25	38.5	40	38.5	61.5
Wood fuel	20	40.0	30	40.0	60.0
Pest and Diseases	10	66.7	5	66.7	33.3
Timber logging	10	66.7	5	18.2	33.3
Clearing land for agriculture	16	61.5	10	61.5	38.5