BIODIVERSITY STATUS AND INDIGENOUS KNOWLEDGE SYSTEMS IN CONSERVING BONI FOREST, GARISSA COUNTY, NORTH EASTERN KENYA

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DECLARATION

I DECLARE THAT THIS IS MY ORIGINAL WORK AND IT HAS NOT BEEN SUBMITTED FOR EXAMINATION IN ANY OTHER UNIVERSITY

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LIST OF ABBREVIATIONS

ADA	Advanced Data Analysis
ANOVA	Analysis of Variance
CBD	Convention on Biodiversity
CBO	Community Based Organization
CFAs	Community Forest Associations
COP	Conference of Parties
DEAP	Dristrict Environment Action Plan
DRSRS	Department of Remote Sensing and Resource Surveys
EDA	Exploratory Data Analysis
EMCA	Environmental Management and Coordination Act
ESA	Environmentally Significant Area
FAO	Food and Agriculture Organisation
GCM	General Circulation Models
GIS	Geographic Infomation System
GPS	Global Positioning System
ICRAF	International Center for Research and Agro Forestry
IEK	Indigenous Environmental Knowledge
IKS	Indigenous knowledge Systems
INPE	The Brazilian National Institute of Space Research
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Nature Conservation
IUFRO	International Union of Forest Research Organisations
KARI	Kenya Agricultural Research Institute
KEFRI	Kenya Forest Research Institute
KIFCON	Kenya Indigenous Forest Conservation
LK	Local Knowledge
LM	Lower Midland Zone
MEA	Multi Lateral Environmental Agreements
NEMA	National Environment Management Authority

NGOs	Non Governmental Organisations
NTFP	Non Timber Forest Products
PCA	Principal Component Analysis
PCQ	Point Centered Quarter
PRSP	Poverty Reduction Strategy Paper
RARC	Regional Assessment and Resources Centre
REA	Rapid Environmental Assessment
SPSS	Statistical Packages for Social Sciences
TDS	Total Dissolved Solids
TEK	Traditional Ecological Knowledge
TK	Traditional Knowledge
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environmental Programme
UON	University of Nairobi
VBR	Village Based Researchers
WCED	World Commission on Environment and Development
WCMC	World Conservation Monitoring Center
WSSD	World Summit on Sustainable Development

ABSTRACT

The conservation of forest bioresources is hampered by lack of information on the resources and on how communities interact with the resources. Historically, the association of local communities with resources such as forests through their Indigenous Knowledge Systems (IKS) has played an important role in the conservation of natural resources. Unfortunately, IKS is fast getting eroded due to what can be loosely termed as “modernization”. As such Kenyan forest resources are threatened because some current conservation methods may not be compatible with forest community livelihoods. This study was undertaken in Boni Forest, Ijara Sub County in Garissa County which is rated as one of the poorest sub counties in Kenya. The aim of the study was to generate information on the forest status in terms of species composition and distribution and to identify how the community has traditionally interacted with the ecosystem. The study findings point towards the need for forest conservation methods which incorporate indigenous conservation.

Vegetation data was collected from 6 transects sampled to represent the variety of ecological conditions in the forest. These were: Mararani (Coastal forests), Mangai (Acacia-Commiphora woodland), Bodhai (Riverine influence on forests), Sankuri (Lungi block of Boni Forest), Hulugho (Acacia–Commiphora woodland), Sangailu (Dryland forests & not gazetted). The data collected included a detailed species inventory and distribution, plant species information on horizontal and vertical dominance, threats to the forest resources, details of plant utilization by communities, information on existing indigenous knowledge systems on plant conservation as well as threats to this knowledge.

The data collected was analyzed using parametric and non parametric methods. The findings indicated that the forests of Ijara Sub County are rich in species composition with a total of 386 plant species recorded of which 130 were woody species. The forests of the southern parts of the sub county had a higher species diversity as indicated by the *Shannon Wiener diversity index*. The dominant families, namely Mimosaceae and Euphorbiaceae accounted for 10.8% and 9.2% respectively of all plant species recorded. *Croton pseudopulchellus* (Pax) was the most abundant while *Dobera glabra* (Forssk), *Newtonia hildebrandtii* (Vatke), *Adansonia digitata* (L), *Diospros cornii* (Chiov) and *Lannea schweinfurthii* (Engl.) dominated in terms of basal area coverage. Other dominant species were *Brachylaena huillensis* O. Hoffm., *Manilkara sulcata* (Engl.), *Acacia nilotica* (L.), Willd.ex Delile and *Combretum constrictum* (Benth) in terms of height and crown. The research established that the forests of the study area were facing a wide range of threats including fires, illegal logging and clearances for agriculture as well as over exploitation for wood fuel. The remote sensing data indicated that the health of the forests was more influenced by climatic variations of rainfall than by human encroachment. The local communities in the area of study had a rich knowledge of the forests as indicated by the diversity of local names, uses of plants and regeneration methods. The communities, especially among the Boni as compared to the Somali, demonstrated good knowledgeof traditional control mechanisms that limited the exploitation of certain species. The study found that the transmission of indigenous knowledge systems from the elderly to the youth was hampered by conversions to new religions, attainment of formal education and the lack of written documents that explained the specific indigenous conservation methods. Indigenous conservation knowledge is therefore an asset that needs to be tapped to sustainably conserve the landscape along with

the biodiversity in the forests. The study recommended the streamlining of government policies on forest conservation to incorporate both scientific and indigenous knowledge systems for conservation of community natural resources. The study also recommended the importance of augmenting conservation measures in order to safeguard the ecosystem services that biodiversity provides and human society needs. Current anthropogenic threats may lead to detrimental and irreversible ecosystem degradation. The findings provide strong arguments to strengthen the case for further research which should be focused on evaluating the response of ecological communities to various anthropogenic pressures. The study specifically recommended the securing of Boni forest by giving it full protection, empowerment of Community Forest Associations (CFAs) and development of a participatory forest management plan.
Key Words: Indigenous knowledge systems, species composition, species density, threats, clearance for agriculture

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CHAPTER ONE: INTRODUCTION

1.1 MAN AND ECOSYSTEM MANAGEMENT

Human society is increasingly becoming aware that ecosystem services are not only limited, but are also threatened by anthropogenic activities. As early as 400 BC, Plato documented how ecosystems could provide more complex services to mankind and he demonstrated that deforestation could lead to soil erosion and the drying of springs (Daily, 1997). Sasaki *et al.*, 2013, studied the relationship between biodiversity and ecosystem functioning and noted that accumulated knowledge generally supports the idea that biodiversity promotes ecosystem functionality and stability, and thus contributes significantly to various ecosystem services. Increasingly there is evidence that serves to highlight the dangerous possibility that loss of biodiversity may result in a decline or loss of crucial ecosystem services (Duffy, 2009; Cardinale *et al*., 2012; Hooper *et al*., 2012).

In many regions, the plight of biodiversity is closely intertwined with that of indigenous cultures. For example, a significant fraction of the world's protected areas, the principal tool for biodiversity conservation, is found within or overlaps with indigenous lands, territories and resources. This remarkable spatial convergence presents both an enormous opportunity as well as a challenge for both conserving biodiversity and supporting Indigenous Peoples' livelihoods (GEF, 2007). Many indigenous and local communities live in territories that are biologically outstanding on a global scale. Traditional indigenous territories have been estimated to cover up to 24 percent of the world's land surface and contain 80 percent of the earth's remaining healthy ecosystems and global biodiversity priority areas (GEF, 2007).

The rapid environmental changes that we continue to experience today rank as one of the most tragic environmental events in the world since they are one of the leading causes of biological extinction of species. Guarino *et al.*, (1995) recognized that plant genetic materials are limited both spatially and temporaly as a resource. This means that any efforts that are geared towards their conservation ought to be assigned an extremely high priority. Plant species store considerable variation among populations thus making their conservation important, not only now, but also in the future. Forests and trees, as part of the natural environment, provide core "services" to citizens, including direct production services, and underlying regulating and supporting services. According to Bromhead (2012), through these products and "flow of services," well managed forests and woodlands contribute directly to jobs and competitiveness, as well as to hungry season food, and back-up cash income in times of need. This inter-relation depicts how the natural environment and human kind are inter-connected. The safeguarding of biodiversity is of the highest priority if human well-being is to be sustained in the face of global change (Díaz *et al*., 2006; Loreau *et al*., 2006).

Climate Change: climate variability and its impacts can cause changes to the ecosystem and alter habitats thus hugely alter biodiversity of the ecosystem. The current climate in Kenya is characterized by large variability in rainfall with occurrence of extreme events in terms of droughts and floods. The following are the major droughts that have occurred since 1980: 1983/84, 1991/92, 1995/96, 1999/2001, 2004/05. The La-Nina related drought of 1999/2001 was thought to be the "worst in the living memory". It was preceded by El-Nino related floods of 1997/98 which were some of the worst in recent times. Another drought occurred in 2004/05 and led to famine in the marginal rainfall areas in Kenya (Nganga, 2006).

Indigenous communities have been responsible for the preservation and maintenance of traditional knowledge and practices that are highly relevant for the sustainable use of biodiversity. This nexus makes it imperative that the rights, interests and livelihoods of indigenous communities are respected and reinforced in all projects/ activity (GEF, 2007).

Land fragmentation, environmental transformation and modification have been concomitant with changing land and resource use patterns in world ecosystems, further enhancing the idea that the relationship between humankind and environment is mutual and co-evolving (Maro, 1974; Lursson, 2001). Over time, however, this relationship has changed as people's livelihood strategies respond to complex sets of environmental, economic and societal dynamics such as population pressure, policy changes and/or ecological change. Forests contain as much as 90% of terrestrial biodiversity, with tropical forests being particularly important in terms of both species richness and their concentration of endemic species (Brooks *et al*., 2006). The world's forests are also globally important carbon stores and sinks

(Gullison *et al*., 2007) and provide a wide variety of other ecosystem services for people, such as protection of fisheries, watersheds and soils. Furthermore, forests constitute an important source of raw materials as the rural poor depend on forest products to meet basic livelihood needs and industry needs forests to provide timber and non-timber products.

1.2 INDIGENOUS KNOWLEDGE SYSTEMS AND ENVIRONMENTAL CONSERVATION

Indigenous knowledge systems (IKS) is the accumulated knowledge, skills and technology of local people derived from their direct interaction with the environment (Altieri, 1987). Indigenous people usually have a vast knowledge of, and capacity for, developing innovative practices and products from their environments. Therefore, the maintenanceof cultural diversity, recognition and protection of IKS can benefit environmental conservation and sustainable management (Maass, 2008). The importance of IKS is evident from the various researches on the subject that have identified ways in which it benefits different groups and individuals who use it. Various studies on the usefulness of IKS have been carried out by researchers such as the study on IKS and management of *Araucaria araucana* (Mol.) forests in the Chilean Andes by Herrmann (2006) which demonstrated the importance of IKS in native forest management. The indigenous knowledge systems and skills of the *Mapuche Pewenche* people of the southern Chilean Andes contributed to the sustainable management of the *A. araucana* forest.

However, IKS is often neglected as a key component that must inform policy-formulation.Instead, it is often undervalued in favour of western scientific knowledge by environmental planners, managers and sometimes the local communities themselves. According to World Resources Institute (1992), learning about and making use of local knowledge helps confirm the value and importance of such knowledge and facilitates its integration into resource management policies and practices.

1.3 INDIGENOUS KNOWLEDGE SYSTEMS AMONGST THE BONI AND SOMALI COMMUNITIES OF IJARA SUB COUNTY

In Kenya, the Boni community (also called the Awer), inhabit the lower sections of the North Eastern region of the country towards the coastal line and bordering Somali and is considered as one of the nearly extinct or unknown marginalized tribes (MPND, 2005). The study focused on the Somali living in Ijara Sub Countynext to the Boni Forest. For many years, most of the area today known as Ijara Sub County was largely unexploited mainly because of insecurity and poor infrastructure. The consequences of this are many and varied, including inadequate data for planning environmental management. An examination of the environmental reports for the area attests to this fact (ALRMP, 2005). Even though some amount of work has been undertaken, this is neither adequate nor conveniently updated, hence the need for further research work. Ecological research studies that can inform forest management plans, proper conservation strategies and sustainable resource exploitation are largely lacking. The knowledge held by both the Boni and the Somali communities is not documented.

The main aim/objective of this research study was therefore to address the problem of inadequate data to use for planning the conservation and management of Boni Forest and also to further understand the contribution of indigenous knowledge systems held by the tribes living adjacent to the Forest.

1.4 STATEMENT OF THE RESEARCH PROBLEM

A review of existing records reveals that there is inadequate data on natural resources in Ijara Sub Countyfor planning the management of the resources. There is inadequate authentic comprehensive ecological documentation detailing the natural resources of Boni Forest, which means that the basis for decision-making for environmental management and conservation can be challenged. There is an increasing need for fresh biodiversity surveys and inventories to allow for sound decision making for environmental planning and also for the purpose of documenting changes in the state of environment. On the other hand the population of resident communities is increasing, their lifestyles changing and the traditional methods that conserved the forest may be getting eroded. There is need to integrate indigenous knowledge systems into national development strategies and policies yet this knowledge is largely not documented and therefore unavailable to policy makers.

The study addressed the following key research questions:

1. What is the forest's plant species composition (plant biodiversity), distribution, density and status?
2. What are the threats to the forest status and species diversity?
3. What are the consequences of habitat destruction on plant species composition and the interaction of these effects and influences on the ecosystem?
4. What indigenous knowledge systems exists for conservation of biological diversity and how can it be incorporated into current plans, programmes and strategies for the management of the forest?
5. What are the factors likely to be causing the erosion of indigenous knowledge systems?

1.5 STUDY GOAL AND OBJECTIVES

The goal of the research study was to assess the status of the forest vegetation in Boni Forest and document the indigenous knowledge systems for the conservation of its biological diversity.

1.5.1 Specific objectives

- i) To document the current state of plant species composition in Boni Forest;
- ii) To determine plant species' diversity, density, abundance and canopy cover of Boni Forest;
- iii) To identify, assess and document threats to Boni Forest;
- iv) To document indigenous knowledge systems related to conservation of biodiversity and utilization of plant species.

1.6 HYPOTHESES

Hypotheses related to objective 1

- i. Boni Forest has a rich biodiversity indicated by species numbers and diversity.

ii. The species diversity, dominance and distribution in Boni Forest have been impacted on negatively by humans.
iii. Boni Forest is degraded due to human activities

Hypothesis related to objective 2

i. The Boni Forest community has a wide variety of uses for the trees of the Forest.

Hypotheses related to objective 3

i. The Boni Forest community is rich in IKS related to forest conservation
ii. Historical conservation of the Boni Forest can be associated with IKS of forest adjacent communities.

1.7 JUSTIFICATION

Whereas studies on species diversity and density may have been conducted for Boni Forest, the information is inadequate and quite scanty. This means that the diversity and plant genetic resources of this forest remain unknown and may be insufficiently represented in existing germplasm collections in the country such as those generated in the "seeds-for-life", a Millennium Seed Bank (MSB) project of the Royal Botanic Gardens, Kew in the United Kingdom, as well as five national partners including KEFRI and the National Museums of Kenya. This research therefore seeks to fill this knowledge gap on the Boni Forest.

In addition, the need for stock taking of plant genetic resources has been emphasised at both national and international levels. International treaties have recognized the close and traditional dependence of many indigenous and local communities on biological resources, notably in the Convention on Biological Diversity (CBD). Article 8(j) of the Convention commits to respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity, promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices, and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices. This has been domesticated in Kenya throughKenya's

Environmental Management and Coordination Act, (EMCA) 1999 in Section 50 which requires that the following activities be undertaken:

- Identify, prepare and maintain an inventory of biological diversity;
- Determine which components of biological diversity are endangered, rare or threatened with extinction;
- Identify potential threats to biological diversity and devise measures to remove or arrest their effects;
- Undertake measures intended to integrate the conservation and sustainable utilization ethic in relation to biological diversity in existing government activities and activities by private persons;
- Protect indigenous property rights of local communities in respect of biological diversity; and,
- Measure the value of unexploited natural resources in terms of watershed protection, influence on climate, cultural and aesthetic value, as well as actual and potential genetic value thereof. (COBD 1992, EMCA, 1999).

The study has greatly contributed to the achievement of the above objectives by providing much needed information which will be used for policy development and planning processes for the management of the Boni Forest by relevant stakeholders including NEMA the custodian of the EMCA.

Another equally important justification for the study is that despite unprecedented interest in local and indigenous knowledge systems (IKS) over the last 20 years, there is still a lack of awareness of the complexity of IKS and of its effective use for ecosystem management. The research expands and refines the understanding of indigenous knowledge systems in order to inform and complement contemporary ecosystem management.

1.8 SCOPE AND LIMITATIONS OF THE STUDY

1.8.1 Geographic and temporal scope

Data collection was spread over a period of three and a half years (November 2007 – November 2011) while data analysis and interpretation including writing the thesis took two years (November 2011-November, 2013). The extent and scale of the study area was Boni Forest including the household area 0-5 km away from the Forest where communities engage in different types of socio-economic activities.

1.8.2 Limitations of the Study

Some of the limitations of the study included the following:

(a) Language barrier

Communicating with the local communities proved a challenge and could only be accomplished through an interpreter.

(b) Insecurity

Ijara Sub County where the study area is located is part of Kenya's North Eastern region (formerly North Eastern Province). The area is particularly insecure due to warring communities, proximity to the lawless Somalia and more recently, the Al Shabaab threat.

(c) Poor infrastructure

Combined with insecurity was the poor infrastructure, particularly poor road network which made access to the study site extremely difficult. Logistical planning required experienced specialists and equipment to be hired. This unnecessarily put a dent on the meager financial resources available.

(d) Time

Although apparently long, the time available for the study proved challenging due to the number of research questions, the nature of the study area, and the fact that the researcher had to combine the study with full time work.

(e) Sectoral boundaries

The study was limited to the scientific realm and did not venture into the occult, spiritism or belief system of the local communities.

1.9 DEFINITION OF TERMS

Biological diversity: The variability among living organisms from all sources including: *inter alia*, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems.

Deforestation: Clearance of forest for agriculture or other uses, resulting in the permanent depletion of the crown cover of trees to less than 10%.

Endangered species: Any species which is in danger of extinction throughout all or a significant portion of its range due to man-made changes in their environment.

***Ex-situ* conservation:** Means literally, off-site conservation. It is the process of protecting an endangered species of plant or animal by removing part of the populationoutside its natural habitat; for example, by removing part of the population from a threatened habitat and placing it in a new location, which may be a wild area or within the care of humans.

Extinct: When the last remaining member of the species has died, or is presumed to have died beyond reasonable doubt (over 10 ten years).

Genetic resources: Genetic material of actual or potential value.

Germplasm: Genetic material capable of propagation.

The Indigenous Knowledge Systems - in its broadest sense, encompasses cultural knowledge; social, political, economic and spiritual; kinship, local politics and other factors which are tied together and influence one another. Indigenous Knowledge Systems is the unique, traditional, local knowledge existing within and developed around the specific conditions of women and men indigenous to a particular geographic area.

In this paper, indigenous knowledge system refers to a body of knowledge that has been generated, tested, improved overtime through the interaction of communities living in and around Boni forest with their supporting ecosystem, and that has been enhanced and safeguarded by norms, values, taboos, rituals and sacredness.

Inventory: A detailed list, report or record of resources, or the process of making such a list.

Hot spot: A hotspot is a terrestrial area with at least 0.5%, or 1500 of the world's ca. 300,000 spp. of vascular plants, and that has lost at least 70% of its primary vegetation. 34 hotspots have been identified globally.

***In situ* conservation:** Refers to on-site conservation. It is the process of protecting an endangered plant or animal species in its natural habitat.

Plant genetic resources: Any material of plant origin of actual or potential value.

Species diversity: The number of different species in a particular area.

Threatened species: Any species of plant or animal which is likely to become an endangered species within the foreseeable future throughout all or significant portion of its range.

Threats: Includes both direct threats and underlying causes synonymous with pressures. A threat is any human activity or process that has caused, is causing or may cause the destruction, degradation and/or impairment of biodiversity and natural processes.

Variety: A plant grouping, within a single botanical taxon of the lowest known rank, defined by the reproducible expression of its distinguishing and other genetic characteristics.

1.10 ASSUMPTIONS OF THE STUDY

The study made the following assumptions:

a) All destruction of biodiversity is human-induced.
   Losses of species or habitats due to natural processes such as fires from lightning or hurricanes were not considered threats to biodiversity. Human-caused increases in

the magnitude or frequency of natural catastrophic events, however, were considered as threats.

b) All threats to biodiversity at a given site can be identified.
   At any given point in time, all the direct threats to biodiversity that exist at the site could be determined.

c) Changes in all threats can be measured or estimated.
   The degree of reduction or increase of all threats at any given time can be systematically, either quantitatively or qualitatively, assessed.

d) Willingness to participate.
   That the communities were willing participants in the surveys and they readily gave information on utilization of indigenous plants including other IKS.

e) Genetic erosion has resulted into endemism, rarity and extinction of plants.
   That there is endemism, rarity and extinction of indigenous plants in the various ecosystems and that the endemic plants identified can be propagated.

f) Government policies influence ecosystems health.
   This study assumed that land use changes and their impacts on vegetation cover and species diversity are influenced by government policy, cultural perception of the local communities of the natural resources, and demographic changes in the surrounding villages.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

One of the ten principles of the Global Biodiversity Strategy recognizes that cultural diversity is closely linked to biodiversity. According to Pilgrim & Pretty (2010), cultural diversity and biodiversity are indistinguishable and the vitality and richness of one is dependent on the other. Reports on the ongoing degradation and unsustainable use of ecosystem services around the world highlight the urgent need to develop strategies to safeguard them (Balvanera *et al*., 2001; van Jaarsveld *et al*., 2005; Chan *et al*., 2006). According to Benis (2009), in order to acquire a comprehensive base of knowledge for genetic resource conservation the inclusion of ecosystem services and their anthropocentric values in conservation planning should be embraced to help improve the relevance and ease implementation of conservation programs.

Although nineteenth century colonialism and social science ignored and sometimes maligned indigenous knowledge systems, it has in recent times become an inevitable ingredient where conservation of biological diversity is considered. There have been proposals for industrialized societies to give up control of ecosystems, and return them to indigenous and marginalized communities for the precise reason that such communities have the ability to coexist with healthy ecosystems (O'Brien, 2010).Indigenous knowledge systemsare particularly important in the sustainable management and conservation of indigenous vegetation diversity or species richness.

2.2 FOREST VEGETATION

Most forests are diverse and dynamic ecosystems containing young and mature trees of different heights with distinct canopies. It is well known that 40% of the world's flora and fauna is found in tropical ecosystems (Renny, 2010). These ecosystems provide a variety of goods and services including timber, firewood, wildlife habitat, phytochemical raw materials and act as gene banks for most of the world's known as well as unknown biodiversity.

Biodiversity is a property of various habitats, with natural forests being very rich in biodiversity and therefore performing many ecological and societal functions thereby providing a wide range of services and goods to different stakeholders (Alonso, 2008). Furthermore, each forest is unique in its contribution to the above roles, partly because of location factors and production systems within and around it. Managing these ecosystems is possible only when their condition is established. According to Alonso, (2008), while some people believe that biodiversity should be protected and restored because of its benefits to man, others believe that it is a moral responsibility to protect biodiversity. This is for the simple reason that all organisms have value, whether we understand their benefits to us or not.

The classification of vegetation has been an important theme of research in botany, ecology, biogeography and other disciplines throughout much of the twentieth century. Increasingly the relationships between indigenous vegetation clearance, habitat loss and fragmentation as well as biodiversity decline are being recognized. The clearance of indigenous vegetation reduces the continuous natural range of ecosystems as well as the diversity of habitats and ecological processes that occur within them with serious impacts on species diversity. The disruption of an ecosystem into a number of isolated 'islands' can result in conditions adverse to the survival of species within the disrupted area (Newmark, 2008).

The vegetation has been variously classified, but the most widely accepted classification recognizes three types as follows: Mixed forest (7,000 ha) in the east, on grey sands. This habitat is relatively dense, tall and undifferentiated, with a diversity of tree species. Characteristic trees include *Combretum schulmannii*, *Drypetes reticulata*, *Afzelia quanzensis*, *Dialium orientale*, *Hymenaea verrucosa* and *Manilkara sansibarensis*. The Brachystegia woodland (7,700 ha), a form of “miombo” woodland or lowland woodland, is floristically and structurally defined and runs in a strip through the approximate centre of the forest, on white, very infertile soil. This relatively open habitat is dominated by *Brachystegia speciformis*. Cynometra forest and thicket, in the west, on red Magarini sands, which is dominated by *Cynometra webberi* with *Manilkara sulcata*, *Oldfieldia somalensis* and (formerly) *Brachylaena huillensis*. (This last tree, much in demand for the carving trade, has been almost logged out from much of the forest). The transition between white and red soil is sudden, and marked by a chain of seasonal ponds. There are two areas of relatively tall Cynometra forest, with a canopy height of upto 20 m, in the north (3,300 ha) and the South (6,000 ha) of this zone. Between these is a lower, scrubbier formation of intermediate Cynometra (11,300 ha) with a canopy height of 7-8 m. The dry north-western part of the Reserve is covered by a low, dense, and often almost impenetrable Cynometra thicket (2,300 ha), with the canopy no more than 5 m high (Glenday, 2005).

Ecological benefits of indigenous vegetation result from its contribution to various vital yet usually undervalued ecosystem services. These include such services as driving the water cycle for water supply, forming and protecting soil, storage and cycling of nutrients, maintaining biodiversity, providing carbon sinks which absorb greenhouse gases and cleanse the atmosphere, and contributing to the maintenance of regional rainfall patterns as well as producing oxygen (Ash 2010).

Indigenous vegetation also has a range of direct economic benefits which include: providing deep rooted vegetation which assists in maintaining water table levels and preventing salinity; providing shade and shelter to stock; providing windbreaks for crops; contributing to soil erosion control; providing habitats for natural predators of crop pests (such as birds and carnivorous insects); maintaining microclimates which assist water retention and quality; providing sites for tourism and recreation; conserving genetic resources for future development of pharmaceutical or agricultural products; and providing timber and other products (such as honey and flowers) (Michigan State University, 2012).

Cultural and social benefits of indigenous vegetation include: providing a sense of identity and place as well as providing recreational amenities. Some forest ecosystems are essential for spiritual uses including worship as is the case for the Kaya Forests in the Coastal Region of Kenya. The Shimba Hills has at least six major forest types, including tall Milicia forest on the deep soils on the plateau top (in Longomwagandi and Makadara forests, and near Kwale town), and on the western escarpment *Afzelia erythophoeum* forest, covering much of the eastern and southern escarpment; *Parama crolobium* forest on particular steep scarp slopesto both east and west; and *Manilkara combretum* forest in the lower, western sector of the plateau (Luke, 2000). The biggest single patch of forest is the south-western sector, including Mkongani North and West. Further east and north, the forest breaks up into a complex mosaic interspersed with scrub and grassland. Very few forest patches are entirely isolated from each other, however, as corridors of forest or forest/scrub formations remain (Luke, 2000). At-least two Kayas, Kwale and Longomwagandi, are situated within the National Reserve (the Kaya forests have spiritual and ceremonial significance to the Mijikenda people of the Kenya coast). The flora of the hills is exceptionally rich and important. A total of 1,100 plant taxa are recorded around 280 of which are endemic to Shimba Hills area and nearly a fifth considered rare globally or in Kenya. This qualifies Shimba as a 'Centre of Plant Diversity', according to the criteria of the association pour l'Etude Taxonomique de la Flore d'Afrique (Luke, 2000). Notable tree species include *Diospyros shimbaensis*, *Cephalosphaera usambarensis*, *Pavetta tarennoides, Synsepalum kassneri*, *Bauhinia mombasae*, *Phyllanthus sacleuxii* and un-described species of *Polyceratocarpus* and *Uvariodendron* (Robertson & Luke 1993).

2.3 SPECIES RICHNESS, DIVERSITY AND ECOSYSTEM SERVICES

2.3.1 Species richness

The simplest and most frequently used measure of biological diversity is species richness, the number of species per unit area. Generally, species richness is used as a measure of diversity within a single ecological community, habitat or micro-habitat (Brown, 2007).

The study of plant communities requires a basic understanding of the abundance, distribution, and number of species present. Yet in obtaining this information it is highly unlikely that scientists can sample the entire vegetation area of interest. In practice, data from numerous small sub-samples provide a basis for extrapolating to a larger area. Such extrapolating must take into account the well-supported observation that estimates of local species richness depend strongly on the number of individuals and the area sampled (Magurran, 2004). Greater species richness means more stability and sustainability of an ecosystem according to Miller & Spoolman (2010), and influences ecological functioning as well, an observation made byChazdon *et al*., (1998)that further explain that although researchers must rely heavily on extrapolations for many kinds of ecological studies, relatively little attention has been focused on improving the accuracy, applicability, and accessibility of species-richness estimators in vegetation studies, particularly in highly diverse tropical ecosystems.

McCarty (2001) notes that new species originate through the process of speciation and species are lost by the process of extinction. He also observes that because extinction and speciation rates are not constant over time, species richness also varies considerably through evolutionary time as well. The number of species in particular taxonomic groups can also vary over time as illustrated by Gunderson, et al., (2009), because at different scales, various sets of mutually reinforcing ecological processes havean impact on temporal, spatial and morphological patterns. Rapid rates of speciation can occur during adaptive radiations, resulting in an increase in the species richness of a taxon. Extinction rates also vary among taxa and over time. According to McCarty (2001), historically, there have been at least five periods of mass extinction during the history of the Earth during which the species richness of the planet was reduced dramatically.

2.3.2 Species diversity

Some studies refer to species richness and species diversity as one while others treat them differently (Adams, 2009). While richness conveys an idea of a bounty of nature, diversity is about the different types of species in the bounty. According to Adams, species diversity combines abundance of species (richness), with a measure of how they are distributed. Globally, biodiversity is essential for cost effective social, ecological and economical development (Kumar, 2012; Sarkar, 2010). Measuring and valuing of biodiversity and ecosystem services has prompted global efforts in developing public policies that mainstream fundamental ecological and economic principles. Tropical forests cover 7 % of the earth's land surface, but harbor more than half of the world's species (Pragasan*et al*., 2009).

East Africa is one of the internationally recognized mega biodiversity regions with three sets of biodiversity values. These include exceptional ecosystems, community and species level diversity with very high levels of localized endemism (WWF, 2012). There are extraordinary high concentrations of some species in East Africa although they are not evenly distributed. One of the world biodiversity hot spots, the Eastern afromontane biodiversity hotspot stretches over a curving arc of widely scattered but biogeographically similar mountains, covering an area of more than 1 million square kilometers and running over a distance of more than 7,000 kilometers from Saudi Arabia to Mozambique and Zimbabwe (Eastern Afromontane Biodiversity Hotspot, 2012). Boni forest is located in this hotspot/eco-region extending from southern Somalia through Kenya and Tanzania to southern Mozambique (Timberlake *et al*., 2011) and is home to at least 1,500 endemic plant species, 16 endemic mammals, 22 endemic birds, 50 endemic reptiles and 33 endemic amphibians (Lovett and Wasser, 1993; Burgess *et al*., 1998; Burgess & Clarke, 2000; Myers *et al*., 2000). It is considered as the hotspot most likely to suffer the most plant and vertebrate extinction for a given loss of habitat and as one of 11 "hyper-hot" priorities for conservation investment (Brooks *et al*. 2002). Bennce 1992 observed that World biodiversity hot spots in the region include the Coastal Forests, the Eastern Afromontane region, the Horn of Africa rangelands and the Islands of the Indian Ocean. However a wide range of more localized hotspots are recognized including the Albertine Rift and Sango Bay in Western Uganda and swamp forests of Tanzania such as Jozani and East Usambara montane forest. Others are the Tana River forests in Kenya, coral reefs and associated in shore communities (Conservation International, 2013). The Great Lakes such as Lakes Victoria and Tanganyika, grassland savannahs such as the Mara and Serengeti in Kenya and Tanzania respectively and Rift Valley soda lakes such as Lake Magadi, Lake Nakuru and Lake Naivasha in Kenya are also considered as biodiversity hot spots (Bennce, 1992).

The study area is part of the Eastern African Coastal Forests (Kenya, Tanzania and Mozambique) which has been recognized as a distinct Global Hotspot for the Conservation of Biodiversity on account of high levels of both endemism (plants and several animal taxa) and species richness, both within and between the many constituent small forest patches. The Coastal Forests Hotspot, are arguably the most threatened of all such hotspots on earth. Endemism is extremely high, over 50% in animal taxa of restricted mobility, and approaching 25% in woody plants. The Coastal Forest mosaic of Eastern Africa is now recognized as an area of major conservation importance on the African continent. The Boni

Forest is an indigenous open canopy Forest and part of the Northern Zanzibar-Inhambane coastal forest mosaic (WDPA, 2012). White, 1970 described the vegetation of Africa and recognized the ZanzibarInhambane Regional Mosaic, and estimated that it possessed ‘at least several hundred’ endemic plant species. This total was upgraded by Clarke (1998) and Clarke *et al*., (2000) to over 1356 species allowing the area to be upgraded to a regional centre of plant endemism, and relabelled as the Swahilian Regional Centre of Endemism. Current data indicate that the Coastal Forests Hotspot contains over 4,000 plant species in more than 1,000 plant genera, of which around 1,750 plant species and 27 genera are endemic. The forest habitat is the most biologically valuable andcontains at least 554 forestdependant endemic plant species, with 17 of the 27 described endemic genera confined to forest habitats. Nonforest vegetation types cover 275,000 km of land (0.3 regional endemic plants per 100 kmof habitat), Coastal Forests cover a total of 6,200 km (15.3 regional endemics per 100 kmof habitat).It is the forest patches that have the highest biodiversity importance per unit area. A substantial proportion of the endemic plants are confined to single forests (for example, the Rondo Forestarea in southern Tanzania has at least 60 strict endemics, the small Litipo Forest, also in southern Tanzania, has at least 30 strict endemics).

The global biodiversity values of the hotspot are widely recognized (Lovett 1988, 1998a, b, c; Myers 1990; Myers *et al*. 2000; Brooks *et al.* 2001; Brooks *et al*. 2002). This hotspot is home toat least 1,500 endemic plant species, 16 endemic mammals, 22 endemic birds, 50 endemicreptiles and 33 endemic amphibians. It is considered as the hotspot most likely to suffer the mostplant and vertebrate extinction for a given loss of habitat and as one of 11 “hyperhot” prioritiesfor conservation investment (Brooks *et al*. 2002). Because of the small area of the hotspot, thedensities of these endemics are among the highest in the world. At the global level, some 0.37percent of all species (in eight major taxa) are estimated to be endemic to the Eastern ArcMountains and 0.20 percent endemic to the Coastal Forest Mosaic (Burgess, 2000). The distribution of these endemic species within the hotspot merits special consideration. First, nearly all the East Africa Coastal Forests (EACF) forest patches have biodiversity values and most contain at least oneendemic species (Burgess & Clarke, 2000). Second, there are many disjunct distributions, particularly amongst the birds and the plants.

Third, there is a hugeturnover of species between patches, especially in the less mobile species. Forests that are only100 km apart can differ in 70 percent of their millipedes (Hoffman, 2000) and in 80 percent oftheir plants (Clarke *et al.* 2000). In some invertebrate taxa, 80-90 percent of species can bestrictly endemic to a single site (Scharff *et al*., 1981; Scharff 1992, 1993; Burgess *et al.*,1998b). These distribution patterns are commonly found in both the Eastern Arc Mountains and thelowland Coastal Forest Mosaic. They indicate that much of the habitat fragmentation in this areais natural and sufficiently ancient for much speciation to have taken place in isolated patches andfor species to have persisted here and there due to stochastic effects. However, over a period ofhundreds or perhaps thousands of years, there has also been considerable loss of habitat andhabitat continuity between the natural fragments (loss of connectivity), as a result of humanactivities. This issue needs careful consideration when conservation interventions are planned.

The projected loss of species diversity could cripple the genetic base required for the continued improvement and maintenance of the world species in current use for food security, medicine and other benefits. It would also deprive evolution of the potential to generate new species. Many food crops of regional or local importance have been relatively neglected by science. There is much potential to look beyond today’s major crops and other species that may have value either in themselves or as sources of genes in the wild (Barker, 2011).

Although it is not certain how much variety and variability is necessary to provide specific goods and services, methods do exist to estimate requirements for maintaining the viability of valued plant and animal populations (Soulé, 1987) as well as the integrity of the underlying natural ecosystems (Karr, 1994). Research findings suggest that a high degree of redundancy exists in the functional assemblages of species-rich ecosystems (Schulze & Mooney, 1993). However, some functional groups consist of only one species, which thereby acts as a "keystone", often supporting a web of numerous other species within an ecological community.

2.3.3 Ecosystem services

Plants are fundamental in stabilizing climate, protecting watersheds and maintaining the chemical balance of the earth (Kumar, 2012). This means that when key species are lost vital ecological services are therefore disrupted. The earth's biodiversity, which includes its ecosystems, species within them and the genes that they contain, is the product of over 3000 million years of evolution. Small changes have accumulated over this period resulting in multitudes of living forms closely adapted to the physical conditions they face and to each other. The Millennium Ecosystem Assessment published in 2005, divided ecosystem services into four categories:

1. Provisioning services, or the supply of goods of direct benefit to people often with a clear monetary value, such as timber from forests, medicinal plants and fish from the oceans, rivers and lakes;

2. Regulating services which include a range of functions that are carried out by ecosystems. These are often of great value but are generally not given a monetary value in conventional markets. They include the regulation of climate through the storing of carbon and control of local rainfall, the removal of pollutants by filtering the air and water and protection from disasters such as landslides and coastal storms;

3. Cultural services which although not providing direct material benefits contribute to wider needs and desires of society and therefore to people's willingness to pay for conservation. They include the spiritual value attached to particular ecosystems such as sacred groves and the aesthetic beauty of landscapes or coastal formations that attract tourists in addition to supporting services that are not of direct benefit to people but essential to the functioning of ecosystems and therefore indirectly responsible for all other services. Examples of these are the formation of soils and the processes of plant growth.

4. Biodiversity is not regarded as an ecosystem service itself but rather as a pre-requisite underpinning each of them. The precise link between the fact of diversity and the

> capacity of an ecosystem to provide services is a complex one and is an area in which science is still developing.

Ecosystem goods and services have significant economic value, even if some of these goods and most of the services are not traded in the market and carry no price tags to alert society to changes in their supply or in the condition of the ecosystems that generate them. Many ecosystem services are largely unrecognized in their global importance or in the crucial role that they play in meeting needs in particular regions. For example, to date there have been no markets that recognize the important contribution of terrestrial and oceanic ecosystems and their biodiversity in absorbing at least half of the carbon that is currently emitted to the atmosphere from human activities, thereby slowing the rate of global climate change.

2.4 THREATS TO BIODIVERSITY

2.4.1 Historical trends in biodiversity loss

According to the World Conservation Union (IUCN) red list of threatened plants, at least one of every eight known plant species on earth is threatened with extinction and this could eventually lead to the disappearance of approximately 34,000 species (IUCN, 2012).

The loss of biological diversity in terms of species and ecosystem depletion is now a reality in Kenya (Ochola *et al*., 2010). There is general realization in the country that two background problems namely poverty and high population growth are the driving forces behind the escalating loss of biodiversity in Kenya (Oppong & Oppong, 2004). Most forms of human production and consumption have the potential to deplete, convert, pollute or otherwise degrade the environment and cause environmental change. Causes of environmental change differ between spatial and temporal scales. Significantly, all rapid change in response to economic needs of communities is likely to be destabilizing to ecosystems leading to reversible and irreversible degradation, thereby affecting energy sources and livelihoods of communities. Environmental changes can drastically affect biologically significant areas as already seen in several places in Africa. Chapman and White (1970) studied vegetation on the Vipya Plateau in Malawi and provide clear evidence that frequent burning can result in the replacement of luxuriant evergreen forest with secondary grassland in less than 500 years without any forest cutting. Stumps of *Ocotea usambarensis*, a tree that grows only in dense forest, were documented several kilometres from the forest edge, two of which were dated around 350 years of age. In another study, Trapnell (1959) examined the ecological results of woodland burning experiments at Ndola in Zambia, a station located at 13^o S and 1200m in elevation. Twenty three years of study using several controlled burning regimes clearly showed that *Brachystegia julbernardia* woodland, which also contains many elements common with the drier woodlands on Madagascar, can be totally destroyed by regular late-season burning, precisely the type of burning regime practiced in Madagascar.

Fires have been associated with forest destruction and loss of biodiversity. Bond *et al*., (2005) illustrate that a small human population has a minimal influence on the well-established forest with its intricate regenerating capacity. Consequently, the impact of man on the vegetation was considered to have been negligible until 5,000 years ago and since then humanity with its most powerful tool, fire, has taken precedence over other natural actors as an environmental modifier (if not destroyer) of the vegetation (Bowman & Murphy, 2010). The sequence of destruction was first as a hunter (with fire), then as a herder (over-grazing), followed by the human as an agriculturist (soil-erosion, eradication of non-edible plants, "weeds"), and finally today more and more as an industrialist (pollution of the air, water and soil) as well as an urban dweller (spreading impervious surfaces: roofs, roads and parking lots better known as concrete jungle).

Various threats have eliminated numerous ecosystems in tropical regions, species and genetically unique populations (Ninan, 2012), including valuable tropical forest genetic resources (FAO, 1990). The priority identification and programmatic focus of numerous international agencies and non-governmental organizations (NGOs) include a long and growing list of threatened habitats and species in the tropics. However, the meaning and value of biodiversity extends well beyond threatened elements to include its functional role and perceived value on all geographic and institutional scales, regardless of degree of uniqueness, rarity or present-level threat. Development in the developing countries posses serious challenges to biodiversity conservation and there is therefore need to profitably sustain the two by trying to reduce the threats.

2.4.2 Biodiversity loss

Habitat damage, especially the conversion of forested land to agriculture (and, often, subsequent abandonment as marginal land) has a long human history. It began in China about 4,000 years ago, was largely completed in Europe by about 400 years ago and swept across the United States of America over the past 200 years or so (Wilson, 2002). Such environmental modification is responsible for the growing challenge of species extinction around the world.

According to Fathom (2012), extinction is a natural event following a chronological perspective and routine. Species extinction represents the ultimate destination of all species and most species that have ever lived have become extinct. The average rate of extinction over the past 200 yrs is 1-2 species per year and 3-4 families per million years. The average duration of a species is 2-10 million years (based on the records for the last 200 million years). There have also been occasional episodes of mass extinction, when many taxa representing a wide array of life forms have gone extinct in the same blink of geological time. Response by or change in the structure or composition of ecosystems (species composition) tends to be more useful as early warning indicators of stress than functional changes such as biogeochemical cycling (WCMC, 1992).

Whether a particular level of forest degradation and biotic impoverishment represents risk in a societal sense depends to a certain degree on the values and preferences held by the particular users of a forest or by the beneficiaries of the flow of forest goods and services. Thus, the assessment of biodiversity risk actually involves two distinct levels. One is the determination of the effect of anthropogenic stress on biotic integrity. The other is the determination of the effect on society of biotic impoverishment, and the long-term diminution of the use and non-use values flowing from ecosystems.

2.4.3 Deforestation and forest biodiversity

From temperate forests to tropical rainforests, deforestation continues to be an urgent environmental issuethat has profound, sometimes devastating, consequences, including social conflict, extinction of plants and animals, and climate change-challenges that are not just local, but global, Fearnside, 2006. Laurance *et al*., 2006 bring out the fact that many species are so specialized to microhabitats within the forest that they can only be found in small areas and that their specialization makes them vulnerable to extinction. In addition to the species lost when an area is totally deforested, the plants and animals in the fragments of forest that remain also become increasingly vulnerable, sometimes even committed, to extinction. Cascading changes in the types of trees, plants, and insects that can survive in the fragments rapidly reduces biodiversity in the forest that remains.

In the Amazon alone, forest loss averages 3-4 million ha per year which is larger than the total area of Belgium (INPE, 1996). Globally, only 20 percent of forests remain intact. Six million hectares of primary forest are lost every year due to deforestation and modification through selective logging and other human interventions (Cincotta & Gorenflo, 2011). Annual deforestation rates rose significantly between the first and second halves (1990-94 vs. 1995-99) of the decade (Laurance *et al*., 2001). There are places where deforestation has decreased yet degradation escalates. An example is the Amazon forest which recorded a 22 percent drop in deforestation between 2009 and 2010 but degradation level rose to 213 percent in the same period (Margulies, 2010). While deforestation indicates total destruction of forest habitats mainly by clear cutting, degradation is a complex phenomenon indicating reduction in the quality of forest ecosystems. So even if deforestation is reducing, the health of forest ecosystems should also be considered.

The United Nations Food and Agriculture Organization (FAO, 1998) reported that Kenya's forests are rapidly declining due to pressure from increased population and other land uses. With most of the country being arid and semi-arid, there is a lot of strain on the rest of the land, especially forest land, since the economy is natural resource based. The productive area which forms about 20% of the country's total land area falls in the medium and high potential agro-ecological zones and is under agriculture, forest and nature reserves. According to

FAO's Forest Resource Assessment 1990, Kenya is classified among the countries with low forest cover of less than 2% of the total land area. The dwindling forest cover has a severe effect on the climate, wildlife, streams, and human population especially forest dwellers.

Kenya is one of the countries in East Africa that has been affected by severe droughts in recent decades (Kinyanjui, 2011). Some authors have attributed the frequency of droughts to the high rate of deforestation. Habitat loss remains the greatest threat to biodiversity. However, increasingly, climate change and globalization are also causing biodiversity loss.

Further research is required to better elucidate the quantitative relationships between indigenous vegetation clearance, habitat loss and fragmentation, and biodiversity decline. A general correlate is that the impact of clearance on biodiversity depends on its biogeographic significance and conservation status. It will tend to be significant in areas where ecosystems contain a relatively high diversity of habitats and high numbers of endemic species with restricted ranges, especially those that are also considered to be threatened.

The immediate effect of clearance on plant and animal species can be significant. For vertebrate animals, comparative estimates of woodland bird densities indicate that between 1000 to 2000 birds permanently lose their habitat for every 100 ha of woodland cleared, while it has been estimated that the clearing of mallee for wheat kills more than 85 per cent of the resident reptiles on average and more than 200 individual reptiles per hectare (Cogger, 1991). Longer term effects of indigenous vegetation clearance on species result from habitat loss and fragmentation working in combination with other threats.

According to Alonso (2008), loss of habitat can adversely affect biodiversity by either reducing or eliminating available habitat for individual species. It can alter population dynamics and ecological interactions, or change biophysical processes that ultimately sustain critical ecological and evolutionary processes. Further to this is the fact that habitat fragmentation contributes both to habitat loss and habitat degradation. Ecological and population integrity can therefore be compromised through habitat degradation. Specific forms and effects of habitat degradation will vary in different major habitat types, but impacts on species ranges, population dynamics, ecological interactions and biophysical drivers can be generally derived for every eco-region. Alonso further explains that wildlife exploitation represents the direct reduction of species populations through human activities with associated consequences on population dynamics, ecological interactions, and biophysical processes. Exploitation can take many forms, from harvesting of plant material, snails and fish to big-game hunting, the kind that has occurred in Kenya and in other East African countries and indeed all over Africa. The effects are similar for all organisms. Nearly all the biological diversity in an ecosystem plays an indirect contributory role by buffering the system from anthropogenic or natural stress (maintenance inputs) or by providing the immediate energy and material requirements.

Physical structures provided by dominant canopy trees, a variety of food webs, mutual interactions involving animals and fruit bearing trees or nectar bearing plants play a key role in ensuring continuity and maintaining stability in ecosystems. Stability is also provided by keystone factors which include physical agents such as fire (Bowman & Murphy, 2010), which significantly disturb or restructure the environment.

The effects of deforestation and changes to the atmosphere, in turn, have caused hardship for local communities (Majtenyi, 2007). Frequent droughts and floods in Eastern Africa can partly be blamed on widespread deforestation in the region, experts have said.

Indigenous peoples live in and have special claims to territories that, in many cases, harbor exceptionally high levels of biodiversity. On a global basis, human cultural diversity is associated with the remaining concentrations of biodiversity. Both cultural diversity and biological diversity are endangered. On a global basis, human cultural diversity is associated with the remaining concentrations of biodiversity. Evidences exist of remarkable overlaps between global mappings of the world's areas of high biological richness and areas of high diversity of languages, the single best indicator of a distinct culture,Schwartzman *et al*., 2005.

A body of conservation and resources management literature suggests that local communities are likely to be better and more efficient managers than centralized agencies Agrawal *et al*., 1989, Ribot 2004. Conservation practices further allude to identification of social ecological linkages and their contribution to the use of locally based ecological knowledge in forest biodiversity conservation. Biodiversity conservation implies the management of human interactions with the variety of life forms and ecosystems so as to maximize thebenefits they provide today and maintain their potential to meet future generations needs and aspirations,Reid *et al.*, 1989. Therefore, in the management of biodiversity,both the ecological and the cultural significance offorests need tobe recognized, Donovan *et al.*, 2004. The challenge now is to bring together indigenous knowledge systems, values and managementpractices withmodernscience, in order to create sustainable and culturally appropriate management strategies.

2.5 INDIGENOUS KNOWLEDGE SYSTEMS

2.5.1 Definition of indigenous knowledge systems

Indigenous knowledge systems (IKS) are also synonymously referred to as local knowledge, indigenous skills, traditional knowledge (TK) or cultural knowledge (Goldman, 2003; Lemaitre, 2011). IKS refers to long-standing traditions and practices of certain regional, indigenous or local communities. This knowledge encompasses wisdom, knowledge, and teachings, skills, experiences and insights of people, applied to maintain or improve their livelihoods (United Nations, 2012). It is orally passed on from person to person over generations. Indigenousknowledge systems are mainly expressed through stories, legends, folklore, rituals, songs and laws. It is obtained through experience and experimentation. This long-term experimentation and experience means that indigenous knowledge systems cannot be quickly replaced by other knowledge systems. It also encompasses the social reality, cultural practices, values and traditions of peoples. The interaction with this knowledge at the spiritual level develops a depth of its own that requires more study and documentation where possible and appropriate. This realm though inadequately understood, has a strong control over the do’s and don’ts of most indigenous peoples. It is the epitome of their belief system and functional values.

Indigenous knowledge systems (IKS) are often in contrast with international knowledge systems generated by research centres and private firms (Homann *et al.*, 2004). Indigenous knowledgesystems are therefore a complex set of knowledge, skills and technologies existing and developed around specific conditions of populations and communities indigenous to a particular geographic area, and form the basis for local level decision-making in a wide range of sectors such as agriculture, nutrition, healthcare, education and training, natural resource management and a host of other activities in rural communities (Warren & Cashman, 2012).

2.5.2 Importance of indigenous knowledge systems in biodiversity conservation

Indigenous knowledge systems are the basis of sustainable national development, and includes the experiences, skills, and insights of the local communities, applied to maintain or improve their livelihood (Biggs, 1989; Bebbington, *et al*., 1993). According to O'Brien (2010), due to their intricate understanding of the host environment, indigenous people have made significant contributions to global knowledge in all areas of development and disciplines such as medicine, agriculture, animal health, meteorology and the environment, which have all had significant inputs from the knowledge base of indigenous peoples.

Indigenous knowledge systems and biodiversity are complementary phenomena essential to human development. IKS represents an immensely valuable database that provides humankind with insights on how numerous communities have interacted with their changing environment including its floral and faunal resources. Such knowledge includes local methods, institutions and techniques for conservation, local use of natural resources and local technologies as well as recipes for the use of natural resources in a sustainable manner, O'Brien (2010).

The failure of the State in consulting local communities, including local experts, before implementing large-scale projects intended for development of the rural poor, often leads to adverse impacts on the livelihood and survival strategies of the targeted populations (NEMA, 2005). The existence of perverse incentives for this approach has blocked space for local innovators and conservators interested in developing and promoting sustainable natural resource practices. The near absence of legal and institutional framework to implement incentives for biodiversity conservation has led to overexploitation of diverse biological resources by the corporate sector (without compensating the indigenous people in any way). Examples of over exploitation of locals abound in East and Southern Africa. Local communities struggling under the pressure of population increase and failures of both market mechanisms as well as State delivery systems have often resorted to the use of sub-optimal livelihood strategies. Indigenous knowledge touches the lives of millions of people directly through the environment in which they live (NEMA, 2005).

2.5.3 Case studies of forest conservation by indigenous knowledge systems in Kenya

Kratz (1999) has documented the case of the Ogiek of the Mau forest complex in Kenya. The Ogiek colonized the forested areas of the Mau between the 1920s and 1940s, after which they lost land to colonial game and forest reserves and to European settlement. They were never allocated land in the general land allocation of the 1960s and have therefore continued to live in the forest. Being hunters and gatherers, the community has clear cut rules regarding forest conservation and this contributed to enabling them co exist peacefully with the forest till the 1980s (Kinyanjui, 2009).

The community had well defined lifestyles based on availability of food in the forest. For example they have clear names of tree species and their period of flowering which correspond to availability of honey. In the recent years however, the community has adopted modern lifestyles that threaten their existence in the forest. They have adopted modern agricultural methods and their children are in formal systems of education. Moreover, their increased population and mingling with other tribes has eroded their traditional conservation systems. Kinyanjui (2009) reported that communities that were allocated land set aside for the forest dweller community in early 2000 were not genuine Ogiek communities. The implication of this on attitudes on conservation is vast and varied.

A more successful case of forest conservation is that of the sacred *Kaya Forests* of the Mijikenda (Robertson, 2002). These forests are situated on the coastal plains and hills of Kenya, and comprise a once extensive lowland forest that has been degraded into patches due to human influence. The forests have high biodiversity with many endemic and rare plants found there. There are over fifty patches of Kaya Forests in the Districts of Kwale, Malindi, Mombasa and Kilifi. The Mijikenda sacred forests have contributed to the protection of approximately 6,000 ha of valued coastal forests through traditional conservation (Lee & Schaaf, 2003).

Mythical tales among the Mijikenda communities indicate that the forests were the hiding places whenever the communities were attacked by the neighbouring Somali, Orma and Galla. The forests were then cleared for settlement leaving the current patches. Many Kayas were preserved as sacred places and burial grounds and this has continued to date (Musila, 2011). Cutting of trees around these sites was prohibited. While the surrounding areas were gradually converted to farmland, the Kaya sites remained as forest patches of varying size and ritual significance.

Regulations have existed for the conservation and use of the Kaya Forests. These include minimal collection of firewood and use of the forests for religious and cultural activities. Fines were imposed on infringements and these were based on the level of infringement. For example minor infringements attracted a fine of livestock or fowls, which were then sacrificed to appease offended spirits. As such the Kaya forests have been protected and their biodiversity maintained.

The Arabuko Forest in Kenya’s coastal region covers an area of 42 000 ha and is home to a community-based enterprise that has provided an incentive for public participation in forest conservation by encouraging sustainable use of forest resources for improved livelihoods (Gordon & Ayiemba, 2003). The Kipepeo (Swahili for butterfly) project earns over US$ 80 000 annually, of which 90 per cent is from the export of butterfly pupae mostly to the USA and Europe. This intervention has generated additional or alternative revenue around the forest and minimized the destruction of forest biodiversity. The project has demonstrated how the principles of sustainable development as highlighted in Article 10 of the Convention on Biological Diversity can be integrated into policy, programmes and projects in order to avoid or minimize adverse impacts on biological diversity. The Kipepeo Project demonstrates the tangible link between biodiversity conservation and sustainable livelihoods by shifting forest utilization from consumptive use of forest wood products such as firewood, charcoal and timber which is unsustainable, to non-consumptive commercial use of forest insects especially butterflies and bees which is sustainable. The initiative has also helped to increase the awareness of communities and national institutions of the ecological and economic importance of insects and their forest habitats by highlighting and demonstrating the direct links between commercial insect and forest conservation. More recently the local community through funding from European Union and other development partners has established other income generating opportunities such as cottage facilities forhire to groups or individuals. This momentum to ensure that livelihoods are sustained more and more away from direct forest resource use will in the long run pay off and the Arabuko Sokoke and other ecosystems will be conserved. Potential for replication of these projects is high. Butterfly farming is now practiced in three other areas within Kenya including the Kakamega Forest, the only true rain forest in the country. Butterfly farming is also being successfully replicated in Tanzania within the East Usambara mountain Forest in the Eastern Arc forest eco-region where the farmers earned 50 000 dollars in 2007.

The Kakamega Forest is an area partly conserved and managed through taboos, informal institutions in which norms, rather than governmental judicial laws and rules determine human behaviour. The Isukha of Western Kenya have for years used the forest as a source of livelihood. Isukha religion through its methods creates environmental awareness that facilitates natural environment resource conservation through oral traditions such as, riddles, proverbs, tales, legends, songs and myths. It ensures appreciation of the beauty of nature of the forest by relating its oral traditions embracing, songs, proverbs and stories related to it. It has tried to shape the attitude of the community members into the appreciation and respect of the forest. It offers the function of disseminating education regarding natural environment to younger generations. The religion governs the use of the forest by use of stipulated rules and regulations. These rules and regulations can be seen in taboos, the idea of sacred and mundane and the attachment of nature to mystical powers. Rules and regulations govern contact with specific natural environmental resources and their utilization. They further stipulate a hierarchy in terms of power concerning the use of specific resources and solving of disputes involving the forest (Ntabo and Omare 2005). The underlying motive has always been conservation of the natural resource and sustainable utilization of the resource.

2.5.4 Indigenous knowledge systems and food security

Much of the world's biological diversity is in the custody of farmers who follow age-old farming and land use practices. These ecologically complex agricultural systems associated with centers of crop genetic diversity include not only the traditional cultivars or 'landraces' that constitute an essential part of our world crop genetic heritage, but also wild plant and animal species that serve humanity as biological resources (Oldfield *et al*., 1991). Prain *et al*., (2000) found that farmers evaluate cultivars using a wide variety of criteria that can be of immense interest and value to crop breeders.

The deliberate maintenance of diversity in domesticated and non-domesticated plants and animals characterizes farming systems across the African continent as well as in most other parts of the world, providing an important opportunity for systematic *in situ* maintenance of genetic resources. Informal agricultural research and development systems parallel those of national governments, providing another opportunity for national agricultural research and extension services to work with the creative interests and activities of farmers and other rural people.

The existence of IKS for food security is threatened by the development process, and the World Bank states that indigenous knowledge systems are 'at risk of becoming extinct' (Ahmed, 1994). Kothari (1995) attributes this to the fact that oral paths are being blocked and people are no longer staying in homogenous community blocks. IK systems in rural communities that were used to ensure food security are rarely documented. Thus, should the method of preservation and perpetuation be disrupted, there is a risk that within one generation, the knowledge could be lost forever (Warren, 1993). Given that IKS is threatened with extinction, the need to document it is justifiable.

2.5.5 Indigenous knowledge systems policy and legislation

Policies on IKS in Kenya have their genesis from as far back as 80 years ago. Already in 1925, the colonial government passed the "Witchcraft Act" of 1925 which outlawed traditional medicine in Kenya. Subsequently, other policies would follow, however none of them directly addressed indigenous knowledge systems especially covering the conservation of biodiversity. The gap in policy issues relevant to IKS in Kenya can be seen from the very small number of publications covering this issue. Globally, a report by the Indigenous People's Council on Bio-colonization (2004) on the Manukan Declaration of the Indigenous Women's Biodiversity Network examined the role of indigenous women on CBD, and explains their relationship and knowledge, biodiversity, health, industrialization, trade and globalization, conflict and militarization. It also includes their recommendations to the Conference of Parties for inclusion in the final decisions of the COP7. Fernández (1994) examined gender policies in IK, and (Mugabe, Kameri-Mbote, & Mutta (2001) reported on Intellectual Property Protection and Traditional Knowledge – an exploration in International Policy Discourse. The article provides a review of literature on intellectual property protection and traditional knowledge.

The Forest Act (GoK, 2005) details the inclusion of local communities in the conservation of forests in Kenya. The Act allows communities to partner with the Kenya Forest Service (KFS) in the management of the forests through management agreements which define forest user groups. Such agreements allow the communities to sustainably exploit the forest by getting firewood, medicinal herbs, honey, grass, poles, prunnings and other products that would support cottage industries. In return the communities provide protection to the forest and this may include bringing in their IKS to the management of the forest. This arrangement allows a non-harmonious community to participate in forest management since the communities are organized into user groups.

2.5.6 Health and medicinal plants

Traditional medicine in general and medicinal plants in particular forms the core of indigenous knowledge systems in many communities in Kenya and in many other parts of the World. Jungerius (1998) examined the indigenous knowledge of landscape-ecological zones and looked at the landscape-ecological perception of herbalists who live in an area with sharp landscape contrasts and drastic changes in land use. The objective of the study was to determine the insight of traditional herbalists in the landscape-ecological factors which control the growth of the plants they use for healing their patients. The extent of this insight determines their capacity to adapt to environmental changes such as deforestation and soil degradation. The important part that traditional medicine plays in the life of the Maasai has been reported by Sindiga (1994).

2.6 Biodiversity and climate change

A great number of climatic factors influence vegetation growth and development (Lieth 1974). Among these parameters, temperature and precipitation are most important in triggering the vegetation growth. Air temperature affects plant mechanisms such as respiration, transpiration, and photosynthesis. It strongly depends on solar radiation.

In temperate and boreal regions, the start of the vegetation growing period is usually related to temperature (e.g., Taylor 1974; Hunter and Lechowicz 1992; Cannell and Smith 1986). Water is also a determinant factor for plant life both in a vapor form in the atmosphere, and in a liquid state, affecting plant physiology and growth process. Annual rainfall and its distribution over the year strongly drive plant development. In tropical dry regions, the beginning of vegetation season is mostly driven by rainfall (e.g., Menaut 1983; Medina 1993; Frankie et al. 1974).

The impacts and economic costs of current climate variability and events in Kenya are already very high. The country is exposed to major floods and droughts, associated with El Niño and La Niña years in addition to other influential regional processes. These extreme events have dramatic impacts on infrastructure, the built environment and the economy, cutting across key sectors including agriculture, industrial processing, manufacturing, tourism, infrastructure, and health. Kenya is also likely to be affected significantly by future climate change. Results from several lines of evidence indicate major reasons for concern. Climate change will lead to impacts and economic costs, though there will also be benefits in some sectors and regions (Nganga 2006).

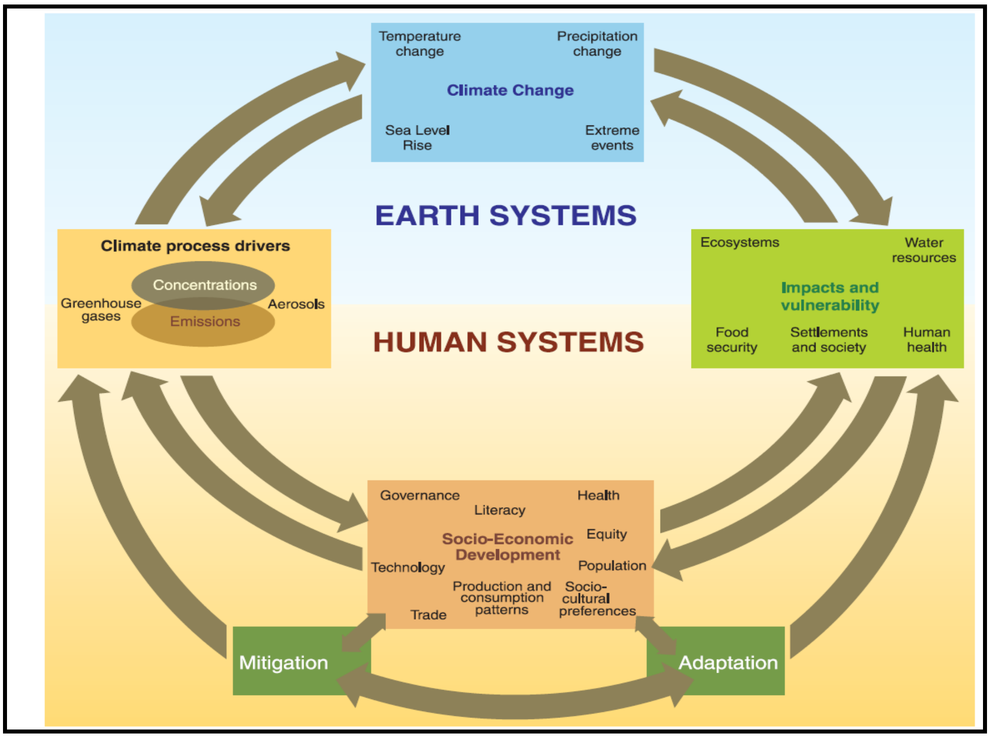


Figure 2.1: Schematic framework of anthropogenic climate change drivers (Adopted from IPCC, Climate change synthesis report, 2007)

2.7 THEORETICAL, CONCEPTUAL AND OPERATIONAL FRAMEWORK

Human well-being and progress toward sustainable development are virtually dependent upon Earth's ecosystems. The ways in which ecosystems are affected by human activities will have consequences for the supply of ecosystem services (including food, fresh water, fuelwood and fiber) and for the prevalence of diseases, the frequency and magnitude of floods and droughts and local as well as global climate. Ecosystems also provide spiritual, recreational, educational and other non material benefits to people. Changes in availability of all these ecosystem services can profoundly affect aspects of human well-being ranging from the rate of economic growth and health and livelihood security to the prevalence and persistence of poverty. Human demands for ecosystem services are growing rapidly. At the same time, humans are altering the capacity of ecosystems to continue to provide many of these services. Management of this relationship is required to enhance the contribution of ecosystems to human well-being without affecting their long-term capacity to provide services.

This study was modeled around the concept of the Millennium Ecosystem Assessment (MA) (see Figure 2.1.). The goal of the MA was to establish the scientific basis for actions needed to enhance the contribution of ecosystems to human well-being without undermining their long-term productivity. The conceptual framework for the MA places human well-being as the central focus for assessment while recognizing that biodiversity and ecosystems also have intrinsic value and that people take decisions concerning ecosystems based on considerations of both well-being and intrinsic value.

Figure 2.1 represents a Millennium Ecosystem Assessment framework which illustrates interrelationships between processes and phenomena, whose combination culminate into change in resource use patterns and loss of biodiversity. The framework has been modified for this study. According to the MA, habitat destruction and plant species diversity loss stem from a complex combination of direct and indirect driving forces. Direct driving forces are those associated with the exploitation of natural resources at a local scale. These include changing land use of a particular niche as replacement of natural vegetation by cultivated land, expansion of agriculture into areas used for grazing, settlement expansion at the expense of natural vegetation and changes into cropping systems. Preparation of agricultural land, for example involves clearing of vegetation, which in turn may reduce vegetation cover and change or lead to a complete loss of primary vegetation.

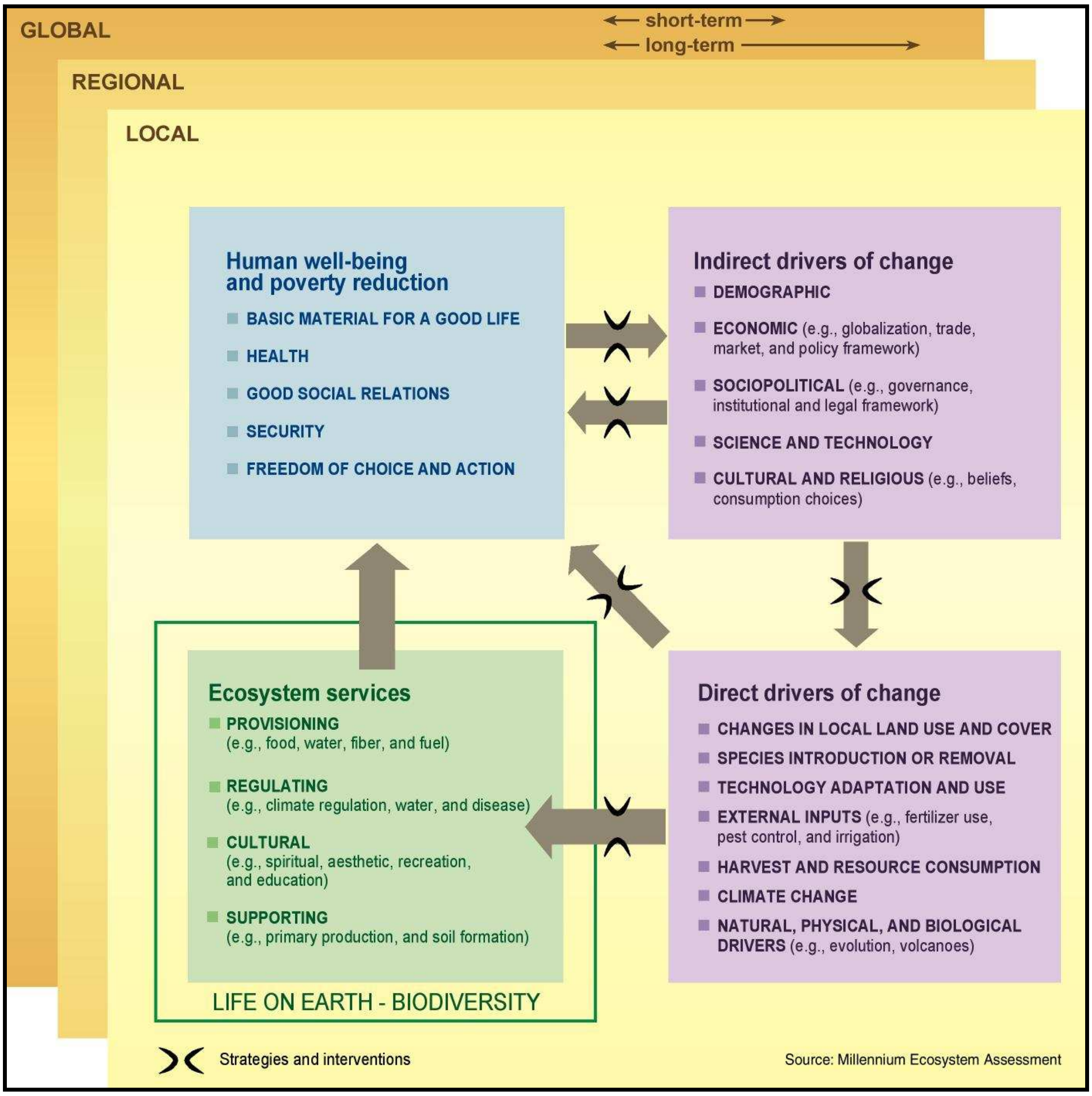


Figure 2.2: Schematic display of the Millenium Ecosystem Assessment Concept

Similarly, settlement expansion at the expense of agricultural and grazing land may result into habitat reduction and vegetation cover loss. At the same time, when grazing land is encroached for agriculture, the grazing area is reduced and the carrying capacity of the land is decreased instigating pressure on the pastureland leading to the alteration of species composition. All these causes, however, are regarded, as a precursor that is a result of the root causes. According to MA, the underlying factors for changing resource use patterns (and their ultimate habitat destruction and plant species loss) include cultural perception of the local communities on forests and biodiversity, adopted or existing forest and land policies, change in forest management responsibilities, demographic changes, macroeconomic policies and structure and poverty as well as inequality. These responses may result into either improved natural resources use and management or negative impacts with such results as degradation of natural ecosystems and biodiversity loss.

The MA conceptual framework assumes that a dynamic interaction exists between people and ecosystems, with the changing human condition serving to both directly and indirectly drive change in ecosystems and with changes in ecosystems causing changes in human well-being. At the same time, many other factors independent of the environment change the human condition and many natural forces influence ecosystems. A full assessment of the interactions between people and ecosystems requires a multi-scale approach, as this better reflects the multi-scale nature of decision making allows the examination of driving forces from outside particular regions and provides a means of examining the differential impact of ecosystem changes and policy responses on different regions and groups within regions. Effective incorporation of different types of knowledge in an assessment can both improve the findings and help to increase their adoption by stakeholders if they see that their information has contributed to those findings. The usefulness of an assessment can be enhanced by identifying and seeking to address its structural biases. Any assessment empowers some stakeholders at the expense of others by virtue of the selection of issues and of expert knowledge to be incorporated.

While it is obvious that humans depend on Earth’s ecosystems, it is another matter altogether to identify, assess, and undertake practical actions that can enhance well-being without undermining ecosystems. Humans influence and are influenced by, ecosystems through multiple interacting pathways. Long-term provision of food in a particular region, for example, depends on the characteristics of the local ecosystem and local agricultural practices as well as global climate change, availability of crop genetic resources, access to markets, local income, rate of local population growth, and so forth. Changes at a local scale that may have positive impacts on the local supply of ecosystem services, such as clearing a forest to increase food production, may at the same time have highly detrimental impacts over larger scales: significant loss of forest cover in upstream areas may reduce dry-season water availability downstream, for instance. Given these complex links between ecosystems and human well being, a prerequisite for both analysis and action is agreement on a basic conceptual framework. A well-designed framework for either assessment or action provides a logical structure for evaluating the system, ensures that the essential components of the system are addressed as well as the relationships among those components, gives appropriate weight to the different components of the system, and highlights important assumptions and gaps in understanding.

In the case of an ecosystem assessment, an appropriate conceptual framework must cut across spatial dimensions from local to global and across temporal dimensions from the recent past to projections into the next century. It must encompass the accessibility and sustainability of natural resources and systems and their products for the benefit of human societies as well as for the maintenance of these systems in their own right. It must examine how the capacities of ecosystems are being compromised or enhanced, and what mechanisms can be brought to bear to improve the access and delivery of services for human well-being. It must examine all resources simultaneously and in an integrated manner, and must evaluate past and potential future trade-offs and their consequences. The MA conceptual framework is designed to assess the consequences of changes in ecosystems for human well-being. It assumes that the central components of human well-being including health, the material minimum for a good life, freedom and choice, health, good social relations, and security can be linked to the status of the environment. The framework allows examination of the degree to which this is true.

Understanding the factors that are causing ecosystem services to change is essential to designing interventions that can have positive benefits for ecosystems and their services. The MA is structured as a multi-scale assessment in order to enable its findings to be of greater use at the many levels of decision-making. A global assessment cannot meet the needs of local farmers, nor can a local assessment meet the collective needs of parties to a global convention. A multi-scale assessment can also help remedy the biases that are inevitably introduced when an evaluation is done at a single geographic scale.

Scientific assessments, particularly global assessments, have generally been based on a particular western epistemology (way of knowing) one that often excludes local knowledge, ignores cultural values, and disregards the needs of local communities. Sources such as lay knowledge or practitioners' knowledge tend to be excluded, since assessment procedures often define the information base for an assessment to be the published scientific literature. Scientists and policy-makers alike have become aware of the need to establish new assessment processes that can accommodate and value these different ways of knowing. For example, a rich body of knowledge concerning the history of ecosystem change and appropriate responses exists within local and traditional knowledge systems, as recognized in principle in the Convention on Biological Diversity. It makes little sense to exclude such knowledge just because it has not been published. Moreover, incorporation of traditional and local knowledge can greatly strengthen the legitimacy of an assessment process in the eyes of indigenous and local communities. Similarly, substantial knowledge concerning both ecosystems and policy interventions is held within the private sector among the "practitioners" of ecosystem management, yet only a small fraction of this information is ever published in the scientific literature. Effective incorporation of different types of knowledge in an assessment can both improve the findings and help to increase their adoption by stakeholders if they believe that their information has contributed to those findings. At the same time, no matter what sources of knowledge are incorporated into an assessment, effective mechanisms must be established to judge whether the information provides a sound basis for decisions.

Relatively little experience can be drawn on today of assessment mechanisms that effectively bridge epistemologies. Within the MA, a concerted effort is made to enable the incorporation of traditional and local knowledge through the establishment of mechanisms for verification even where that knowledge is not first published in peer-reviewed literature.

The study assessed resource use and indirect drivers of biodiversity ecosystem services loss and degradation, focusing mainly on the Boni Forest and the area 5 km around the forest. An examination of pressures causing habitat loss and over exploitation was also undertaken with a focus on species density and diversity. Ecosystems processes and how they link into ecosystem goods and services including cultural influences were inferred.

Whilst the MA framework allows for cultural assessment under the ecosystem goods and services window with the assumption that this then influences human well being, Traditional Ecological Knowledge, amended to include wisdom, or further amended to include innovation and practices, has become increasingly popular with many acknowledging that more than knowledge is involved (Trosper, 2007). IKS can be represented as emerging from a complex system composed of three subsystems: Context, Practice and Belief (CPB). Contextual knowledge portrays learning due to history, demographic factors and biophysical features of place. Knowledge as practice portrays meaningful action, through physical interaction and experiential learning. Knowledge as belief portrays the influence that spirituality and values have on how people act within their ecosystem. This can be illustrated as follows:

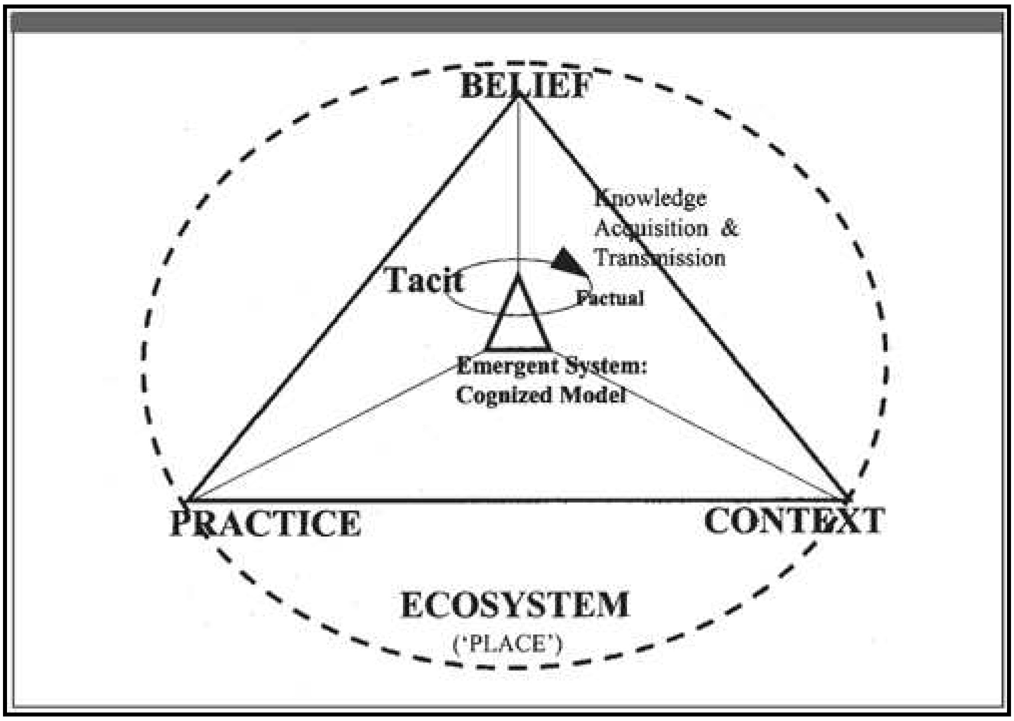


Figure 2.3.Conceptual Framework: Emergence of IKS from a Traditional System

The CPB framework can be used to represent structure and organization in the complex ecosystem and it represents knowledge as engagement rather than as abstract understanding. The use of the CPB complex as a basis for understanding local knowledge systems is intended to give some order to the myriad of ecosystem variables that influence IKS. It is based on the assumption that by understanding the whole, properties emerge that are not evident in the component parts. Indigenous ecological knowledge (shown in the diagram as the triangle 'above' the three CPB components) is considered the 'property' that emerges from the interaction of multiple component parts. Structure (the CPB variables in the socio-ecological complex) and organization (cognitive process which brings forth reality) are reciprocally inter-related. Changes in structure may influence changes in cognition – changes in cognition also influence changes in structure.

Within a complex system, IEK constitutes a metaphorical mental model, which represents context-based conceptions of the environment and provides the basis for action in daily life. Mental models are not designed to conform to the reality of the outsider, but are meant to represent an engagement of people within ecosystems. The conceptual framework also incorporates elements of scale.The spatial dimension of IKS is the holistic, embedded or 'place-based' aspect of knowledge, signifying the situation (at any one point in time) within the social, cultural, historical and biophysical aspects of locale or 'place'. The temporal scale of IKS is the change that may occur in any of the CPB variables and the influence this has on emergent IKS. The time scale is also shown in the diagram as the cycle of knowledge acquisition and transfer (shown as the cycle in the center of the triangle). Both factual (explicit) knowledge and tacit (implicit) knowledge constitute the mental model.

As the CPB complex changes, in time and space, IKS also changes which in turn, influences CPB. The emergent knowledge is shown as displaced from the local ecosystem due to the influence of several driving forces. For example, a component of the belief subsystem is the use of specific 'magical' practices to cultivate the traditional crop. This has changed over both time and in space: i.e., there were several practices that were specifically linked to particular times in the year or a person's life, that changed to practices determined by external drivers. The change in the spatial dimension is from practicing traditional forms of cultivation that included worship of deceased ancestors who resided over gardens, to an introduced belief system. The change in both time and space of this component has accelerated the loss of the local knowledge that is associated with traditional forms of spirituality. Traditional beliefs are strongly associated with the relationship to the land and resource base. As local knowledge becomes 'lifted' from local context, it becomes less tacit and experiential and more explicit and factual, influenced more by factors outside the local ecosystem.

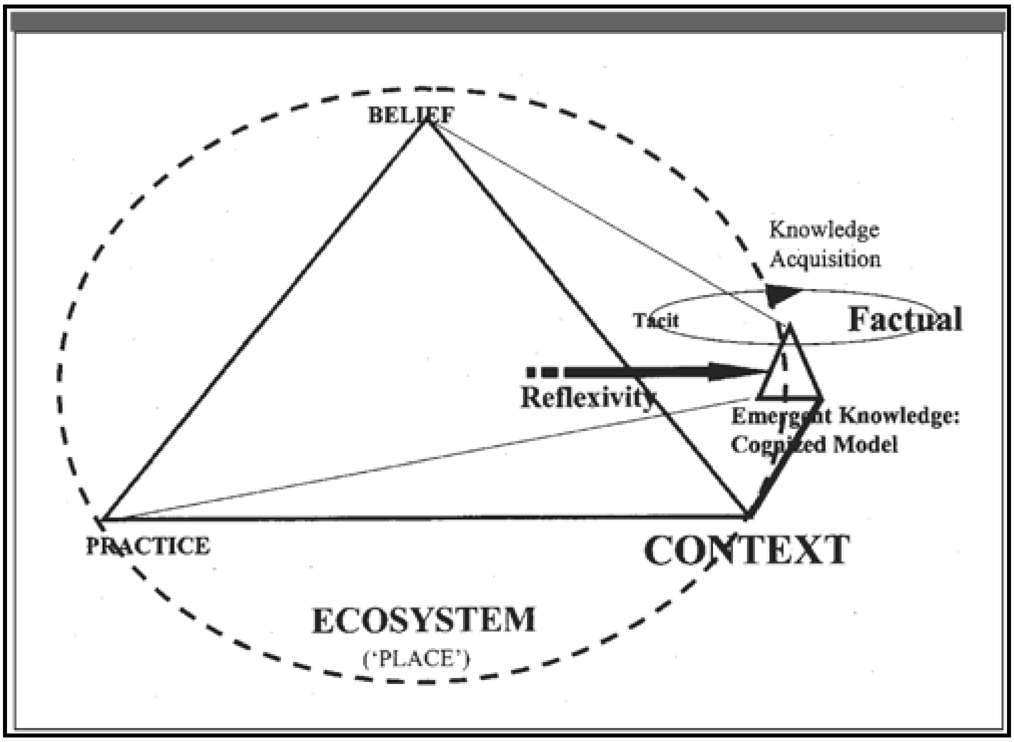


Figure 2.4: Conceptual Framework: Shifting to Disembedded IEK as Knowledge is Acquired

The process of reflexivity shown in the figure above emerges and influences the knowledge production cycle. Reflexivity, while displacing IEK further towards the explicit or abstract end of the knowledge continuum, is referred to as the 'formalization' of knowledge. It is a process that may become an important, if not critical, process enabling knowledge holders to transcend time and reclaim 'traditional' knowledge that was once used in a specific context and apply it within a new context. Reflexivity may also be considered part of the resilience and adaptive capacity of a community. The concept of reflexivity as introspection may be a means to locate both traditional and contemporary IKS in the current context of ecosystem management.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 DESCRIPTION OF STUDY AREA

Ijara Sub County is one of the four Districts forming Garissa County in North Eastern Kenya and borders Garissa District to the North, Lamu District to the South, Tana River District to the West and the Republic of Somalia to the East. Ijara Sub County was carved out of Garissa District on the 20th of May, 2000 (Figure 3.1). The District lies approximately between latitude 20 03' & 00 75'S and longitude 390 96 & 410 55'E. The District covers an area of 11,332 km^2. Boni National Reserve lies at the southeastern end of Kenya's northern border with Somalia in Ijara Sub County. Administratively, Ijara Sub County has 4 divisions, 16 locations and 28 sub-locations.

3.1.1 Topography and soils

Ijara Sub County is characterized by low undulating plains with low lying altitude ranging between sea level and 90m above sea level (ALRMP, 2005). Boni Forest lies in agro-ecological zones V and VI. Its soils are mostly sandy with poor structure, but there are also extensive areas of black and dark brown clays (Kuchar and Mwendwa, 1982). These soils are generally well protected because of dense plant cover. On the western side along the Tana Belt, soils are mostly alluvial while areas close to the Boni Forest consist of sand rich forest soils. Between these two types of soils are the black cotton soils that dominate

3.1.2 Climate

Ijara Sub County has semi arid climatic conditions, a low altitude, and high temperatures throughout the year at round 25^{0}C to 38^{0}C. The mean annual rainfall ranges from 750 mm to 1,000 mm due to the influence of the coastal winds from the Indian Ocean. The climate in the area is heavily influenced by the north-east and south-west monsoons blowing from the Indian Ocean (GoK, 2009). Over longer periods of time there has been a discernable warming trend. Natural causes can explain only a small part of this warming which is already manifesting itself in frequent droughts and unreliable rains. These unpredictable weather positions cause the already poor community to undergo untold suffering, and unwittingly turn to the biodiversity in forests and other ecosystems for alternative livelihoods.

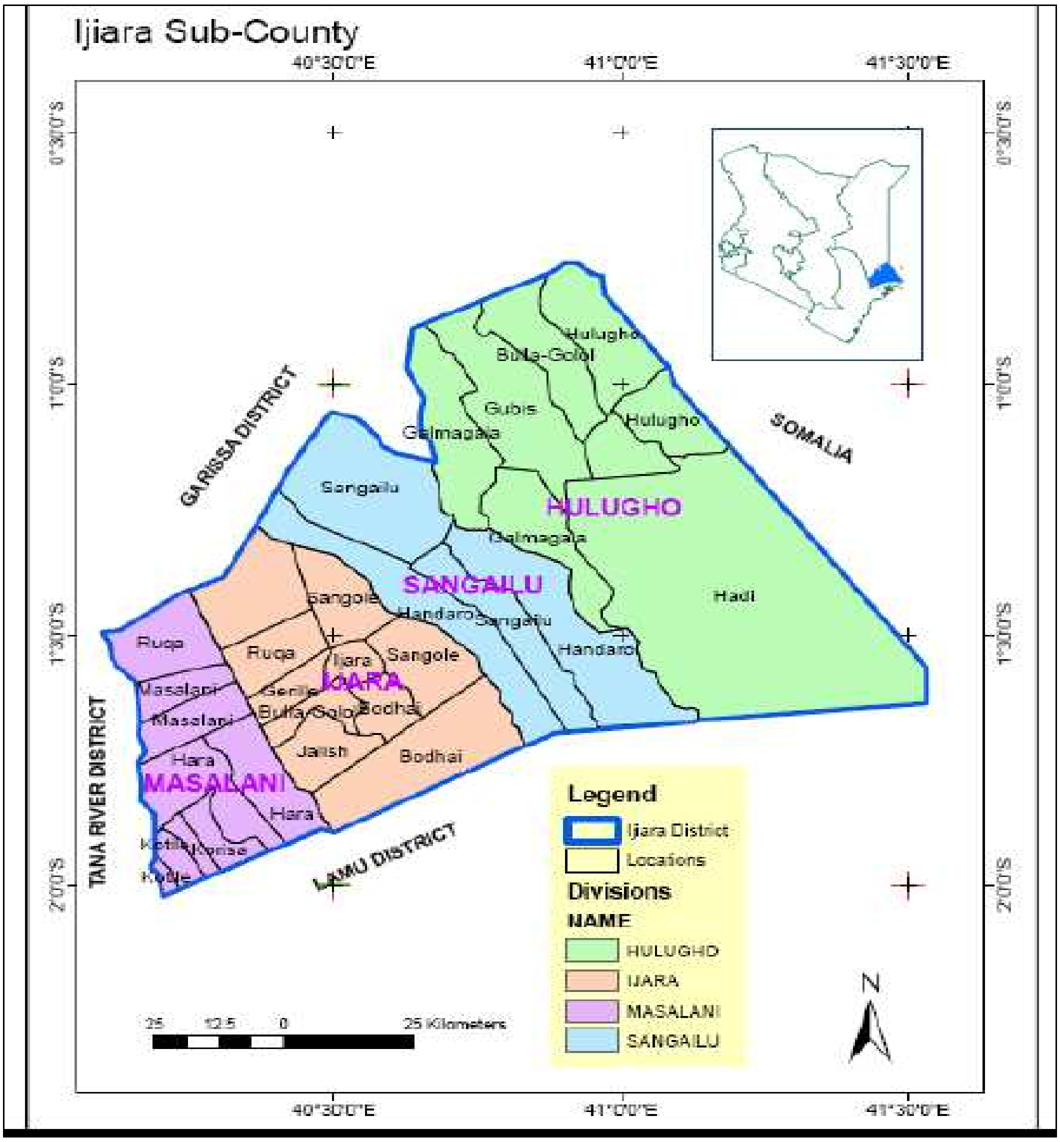


Figure 3.1: Map showing administrative boundaries of study Area (Source, Researcher, 2014)

3.1.3 Biodiversity and ecosystems

There are two small fresh water lakes in Ijara Sub County, namely Lakes Hadhi and Jerrei which are located in Boni Forest and are a source of water for domestic consumption and for livestock (ALRMP, 2005). The vegetation of Ijara Sub County is characterized by a great ecological diversity. In general the central-northern part has open areas of shrub savannah and open woody vegetation is predominant. In the south-western and south-eastern sides forests are dominant. Ijara Sub County is the only district in North Eastern Province with a forest cover.

Boni forest is a major ecosystem in Ijara Sub County. It lies approximately from 1°76′ to 1°25′N and 40°83′ to 41°66′E. The Forest reserve which was created as a dry season sanctuary for elephants from Ijara and Lamu Districts stretches all the way to the Eastern part of Lamu District and the Western section of Badaade District of Somalia. In Ijara Sub County, the Forest covers an area of 283,500 hectares which is about a quarter of the district area. In Boni Forest, 1,339 km^2 has been gazetted as Boni National Reserve and is managed by the Kenya Wildlife Services (KWS), while 1,145 km^2 is classified as trust land. The Forest lies in a plain with an altitude ranging between 0-200 meters above sea level.

The Boni Forest, after which the National Reserve is named, is named after the hunter-gatherer Boni people. It is an indigenous open canopy Forest and part of the Northern Zanzibar-Inhambane coastal forest mosaic (WDPA, 2012). Boni Forest, often referred to as home of the elephant has several confirmed wildlife species (ALRMP, 2005). These include aardwolf, buffalo, bush-pig, bush-buck, caracal, cheetah, common duiker, generuk, Grant's gazelle, hippopotamus, honey badger, black-backed jackal, Kirk's dik dik, leopard, lesser kudu, lion, oribi, porcupine, red duiker, spotted hyena, squirrel, topi, vervet monkeys, yellow baboon, elephants, warthog, waterbuck, wild dog, zebra, the hirola, colubus monkey, giraffes and various types of snakes. Boni Forest has 2 threatened animal species - the African elephant (*Loxodonta africana*) and the elephant shrew (*Rhynchocyon sp*.). Human-wildlife conflict is increasingly reported as pressure for land grows, leading to competition for resources between wildlife and human beings. Along Tana River, where irrigation agriculture is practiced, damage to crops by wildlife is significant. Attacks on children and livestock by crocodiles from the river have also been reported (GoK, 2009).

Although the area is mostly hot and dry, wetlands in and around the Boni Forest offer an array of water birds and birds of prey. There are more than 152 species of birds (ARLMP, 2005) including African darter, hamerkop, African fish eagle, Hartlaub's bustard, sanderling, Fischer's turaco, fiery-necked nightjar. Brown-hooded kingfisher, brown-breasted barbet, carmine and European bee-eater, honey buzzard, palmnut vulture, southern banded harrier eagle and violet-breasted sunbird are available for spotting.

3.1.4 Human population characteristics and land use

Ijara Sub County is sparsely populated with a population of 62,642 people, consisting of 11,445 households with an average size of 5 persons per household (GoK, 2009). The settlement pattern in the district is described in terms of market centers that have high human settlement due to availability of basic facilities. Most people are settled along River Tana as well as in urban and trading centers and in other areas with proximity to sources of water. As one moves towards the largely rural areas, the settlement pattern predictably follows sources of water. The inhabitants of Ijara earn their livelihoods mainly from pastoralism and subsistence agriculture. Presently over 80% of the land is under livestock production and only 10% under rainfed agriculture although a substantial portion of the area has great potential for rainfed agriculture. The agricultural potential of the district is not fully exploited, despite the rains and fertile soils suitable for crop production along the River Tana. This is because the district's people are generally pastoralists and tend to look down upon farming as an inferior way of life.

The District has a high profile of poverty accounting for 59% of the total population (ALRMP, 2005). The causes for this poverty range from unexploited natural resources, poor or inadequate infrastructure to open up the district, high illiteracy levels, lack of employment opportunities and poor livestock and agricultural marketing systems. The perceived unwillingness of government to give full-fledged property rights in land to the local communities is cited as the chief obstacle to development (ALRMP, 2005). Conflicts among the resident pastoral and agricultural communities could also be cited as a major factor resulting to poverty. Such conflicts have led to destruction of property and the residents are also not motivated to invest their resources fully because such resources can be lost during periods of conflict.

The ethnic groups occupying Ijara Sub County can be divided into 2: the Somali Abdalla community and the Boni community, also known as the Awer. The Abdalla live in Ijara and Garissa districts of North Eastern Province, Kenya. They belong to the Cushitic Ogden clan of the Somali tribe of East Africa. Their origin could be traced to the Horn of Africa through the Ogadenia Province of Ethiopia. They are predominantly nomadic pastoralists who keep cattle and shoats (goat and sheep). The area they inhabit experiences recurrent drought with a cycle of 4-5 years. The Abdalla are predominantly Sunni Muslims with strong conservative Islamic backgrounds.

The Boni, whose ancestors were the Sam, an Eastern Cushitic language group who entered the area about 2,000 years ago and whose name, for some reason, derives from their word for "nose" (EDGE, 2012), live in Lamu and Ijara Sub Counties. They are called “Boni”, meaning (some believe) people of a lower caste system by their Somali neighbours. They are hunters and gatherers and live in the Boni and Dodori Forest Reserves. In Lamu, Garissa and Tana River Districts the Boni were assimilated by the Bajun, Somali, Pokomo and Oromo. The Boni resident population on Kenyan side is about 2,000 people according to the 1999 census and they are indigenous forest dwellers. The community however started practicing farming a few years ago (ALRMP, 2005), an activity that could affect the forest in which they live.

3.2 RESEARCH TIMEFRAME

Familiarization with the study area and the administrative set up in the district was the initial activity in the research process. This involved holding initial consultative meetings including administration of a questionnaire to Heads of Departments which was then followed by the training of research assistants. These activities were undertaken in the first half of 2008. Very crucial meetings were also held with the then District Commissioner which generated useful information on the impact of cross-border activities on the ecosystems. During the same period, identification of sampling sites and species inventory was undertaken, by considering the physiognomic variations of the vegetation. Phase two of the work was undertaken in the second half of 2008, just the time before the next predicted long rains.

Data collecting was undertaken again after the heavy rains in early 2009 and again in August 2010.

3.3 RESEARCH DESIGN AND GENERAL APPROACH

The first phase of this thesis was based on collecting vegetation data on the forest and the neighboring ecosystems. The data was subsequently analyzed using various analytical tools followed by interpretation. The second phase involved collection of qualitative data using semi-structured interviews and observations. The interviews were transcribed and later analysed for emerging themes. Data collected from the second phase was used to explain findings of phase one in an attempt to propose conservation methods for the forest with indigenous knowledge systems as a major tool for forest conservation. The research methodology was therefore developed with the goal, objectives and research questions in mind. The next section systematically outlines the methodology under each objective and takes into consideration the research questions as well.

3.4 VEGETATION ASSESSMENT

3.4.1 Sampling strategy

A total of 6 belt transects running from south to north each measuring 8 km long were located in the study area based on vegetation type and proximity to settlements. At 1 km intervals along transects sampling points were located to collect vegetation data. Table 3.1 shows the specific locality sampled and other relevant features for each transect while Figure 3.4 shows the location of the transects on a map of the area.

3.4.2 Location of transects and theirfeatures

The study identified the local ecological resources and niches, grouped into transects which formed the study units. These natural resources include open access and common property resources which may be vital to the functioning of local ecosystems. These are presented in Table 3.1:

Table 3.1: Location of transects and their features

Transect	Location / Area	Vegetation zone
1.	Mararani	In Boni Forest reserve on the southern side of Ijara Sub County. The vegetation was largely coastal with a variety of species and trees have a closed canopy
2.	Mangai	Located on the southern side of Ijara Sub County. Transect located outside Boni Forest on the northern side. The coastal effect on vegetation slightly reduced giving rise to Acacia-commiphora woodland. The transect crossed trails used by Boni community to reach water sources especially during drought.
3.	Bodhai	Located in Bodhai area which is on the south western side of Ijara next to the riverine forest of the Tana River. This comprised closed canopy forests due to the riverine effects and the adjacent coastal forests.
4.	Sankuri	Located in Lungi block of Boni Forest. Transect started from the hilltop with thick forest. The forest had closed canopy.
5.	Hulugho	Located in northern side of Ijara Sub County where it is drier in Acacia- commiphora woodland. Area had high livestock and wildlife density.
6.	Sangailu	Located in the northern side of Ijara where it was generally dry. Land was communally owned and the forests were not gazzetted.

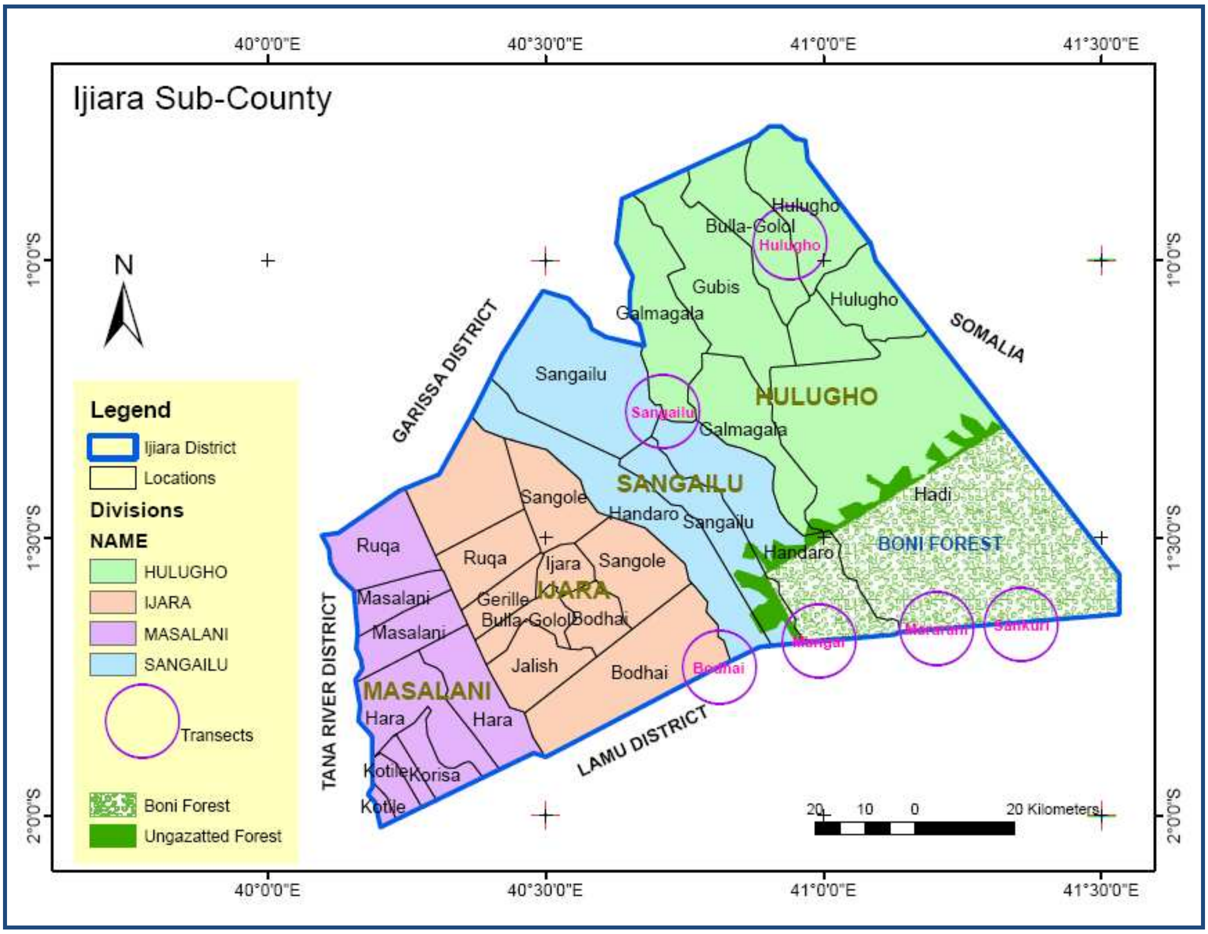
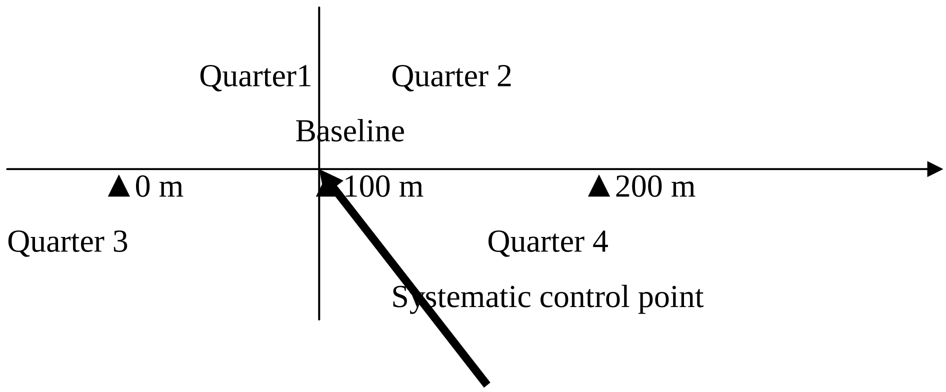


Figure 3.2: Location of study transects (Source, Researcher, 2014)

3.4.3 Assessment of woody layer

The Point-Centred Quarter (PCQ) method was used to collect data on the woody vegetation in transects set for herbaceous data sampling. The PCQ is a distance method for sampling woody vegetation, composition and density (Mueller, 1974). Using a Global Positioning System (GPS), sampling points were located along each transect. The area around each point was divided into four equal quadrants by making use of a second line perpendicular to the transect line. The tree species nearest to the sampling point in each quarter was identified. The distance to the nearest tree or shrub would be estimated in each of the 4 quarters at each systematic observation point. The accuracy of the PCQ method increases with the number of observation points. Basically a minimum of 20 to 30 observations is recommended for better output (Herlocker, 1999; Mwaura & Kaburu, 2008).

Species richness was then considered as the total number of different woody species recorded in the four quarters of each sampling site. Samples of plant species not identified in the field were pressed and taken for identification at the national herbarium in the National Museums of Kenya in Nairobi.



Two sets of data were collected using PCQ method; plants higher than 3 meters to represent the upper canopy and plants less than 3 meters height for the lower canopy. Additional parameters collected to quantify structure of the communities included:

Stem diameter to enable computation of horizontal dominance –

Plant height to enable assessment of vertical stratification of the community –

Canopy diameter measured both along the transect direction and perpendicularly to enable estimation of vegetation cover –

3.4.4 Species density

The data from the line transects was used to asses density, frequency, percentage cover and diversity of trees, shrubs, herbs and graminoides found on the land surface. A consistent compass direction at right angles to a main topographic feature was chosen. A starting point 20 meters from the forest was used. Using a 100-ft long measuring tape, plots of 20m X 20m were systematically selected along the transect at intervals of 100m. The tape measure would be laid across the trees/shrubs/herbs/graminoides on the earth surface and random samples assessed along the transects using quadrats. For forest cover, one would walk along the measuring tape and count the number of times a part of plant intersected the tape measure at the 1-foot mark. The number of times counted would make the percentage value. The

Braun-Banquet cover abundance scale (Brown, 1984), as modified by Vander Maarel and Werger (1978) was used alongside.

3.4.5 Species diversity computation

Species diversity was calculated using the Shannon-Weiner method (Shannon and Wiener 1949 cited in Harris *et al.*, 1983). The index, which varies from zero for one species and increases with increase of species heterogeneity, has previously been used in vegetation studies in Kenya (Mwaura 1999, & Mwaura *et al.*, 2005) and has been recognized as important criteria for the assessment of conservation potential, environmental quality and ecological value (Harris *et al.*, 1983). The index was computed from the species present in atransect and calculated using the following expression according to Harris *et al.* (1983): $H' = -\sum[n_i/N] \log_e [n_i/N]$

Where;

- H' is the Shannon Index,
- n_i is the total number of individuals of the i_{th} species in a sample,
- N is the total number of all individuals of all species in a sample, and
- n_i/N is the proportion of the i_{th} species in a sample.

3.4.6 Vegetation similarity assessment

Comparative analysis of woody species characteristics between transects was undertaken using Sorenson's index of similarity (C_S) according to Krebs (1989) and Balsega *et al* (2007). The Sorenson's index of similarity (C_S) was then calculated between each of the transects as:

$C_s = 2\{(2a)/ (2a + b + c)\}$

Where;

- a = the number of species unique in given area A (Transect 1),
- b = number of species unique to area B (Transect 2),
- c = number of species shared by area A and B (Transects 1 & 2).

The index ranges from 0, when communities in two transects share no species in common to 1 when two communities are totally identical (Krebs 1989).

3.4.7 Species relative abundance

Relative abundance referred to is an index of dominance that compares the number of individuals of a species identified with the total number of individual plants counted in the whole sample (Kinyanjui 2009). The index is then converted to a percentage value to show the relative abundance of a species in a sample point. Relative abundance was calculated per species in each transect as:

Relative abundance = (Number of individuals of a species /Total number of individuals) X 100.

The species were then ranked from the most abundant to the lowest in each transect.

3.4.8 Relative dominance by basal area and by crown cover

Magurran (1988) described the relative dominance of a species as dependent on its contribution to the total basal area in a transect. The index calculates the sum of the basal areas of all individuals of a specific species and compares it to the total basal area of the transect. The initial step was to convert stem diameter measures into basal areas using the formula Basal Area = πr^2. Then a summation of basal areas for each species was undertaken followed by a ranking of species from the highest basal area to the species with the least basal area. Relative dominance which is converted to a percentage was calculated as;

$$\textit{Relative dominance (\%)} = \left(\frac{Gi}{G}\right) x100$$

Where

Gi - Total basal area of species *i* in the plot

G - Total basal area for all species in the plot

3.4.9 Tree Species importance values

Magurran (1988) described a further index of vegetation dominance which apart from incorporating relative dominance by basal areas and relative abundance by numbers adds another factor of frequency of occurrence of the species among the sampling points. The importance value of a species was calculated as the sum of relative dominance, relative abundance and relative frequency converted to a percentage. Species were then ranked per transect to identify the most dominant in all aspects of big tree sizes, many individuals and wide distribution in a study location.

3.4.10 Threat analysis

Observation is a vital feature of the ethnographic case study approach, as it allows the researcher to "collect live data from live situations" (Cohen *et al*., 2000). At each transect four quadrats; each measuring 10 x 20 meters were sampled. Each quadrat was 200m^2, which is, 0.2 hectares. Data was taken at 20m intervals within each transect. The distance between adjacent quadrats was 100 meters. The monitoring site was the area within which the four belts were laid.

In each transect every tree with a 12 cm diameter girth was recorded, by species name, girth and height. Evidence of disturbance per tree was noted, as cut branches, debarked or root harvested. Tree stamps were noted as "cut trees". Other records included slope gullies, overall vegetation type and levels of dunging, weighted between 1 (being the lowest occurrence of dunging) and 5 (being the highest occurrence). Evidence of utilization of other forest products was also recorded. Other threats to vegetation such as wild fires, farming, slashing, were also recorded. Appendix 1A shows the recording data sheet.

The threat levels per transect were ranked based on the criteria described in Table 3.2. An analysis of variance was used to compare threats among transects using data collected from the 80 sampling points per transect. A pair wise ranking (Russel, 2001) was used to rate the degradation indicators at each of the study areas.

Table 3.2: Criteria for ranking threat level in the study area

Threat level	Remarks
0	No evidence of any encroachment. If there were fallen trees, the falling was not associated to human activities
1	No direct evidence of human activities. Human activities were inferred e.g. Presence of livestock tracks, cow dung
2	Minimal evidence of human activities. Included debarking of a few trees and some branches of trees
3	Evidence of human activities could be rated as moderate. Includes extensive debarking of trees and cutting of tree branches
4	Evidence of human disturbance could be rated as "severe". Included presence of fallen trees, some evidence of fires, massive debarking, presence of open areas that could be related to human activities, presence of a few stumps
5	Evidence of human disturbance could be rated as "very severe". Included farming in the forest, use of fires to clear vegetation, massive logging and many tree stumps

3.5 MONITORING EFFECTS OF CLIMATE CHANGE ON VEGETATION

Data on the Normalised Difference Vegatation Index (NDVI), an index of vegetation health and density that is recorded by remote sensing methods (Eastman, 2001) was processed at the Department of Resource Surveys and Remote Sensing (DRSRS). The data is obtained from a 1 km resolution SPOT vegetation sensor and recorded at 10 day intervals for all vegetation types of Kenya based on the AFRICOVER land cover classification (Kinyanjui, 2011). The values of NDVI were extracted for the closed woody vegetation type in Boni Forest. This is the vegetation type comprising closed forests.

The data was analysed to identify vegetation variations in the period 2000 – 2011. Using this data, trend lines were plotted to show variations in vegetation over the 12 year period and also among seasons while ANOVA tests were done to test evidence of degradation over time either as an indicator of the effect of climate variability or anthopogenic forces.

3.6 DOCUMENTATION OF INDIGENOUS KNOWLEDGE SYSTEMS

3.6.1 Sampling technique

The samples were drawn from the eleven villages (Malta-arba, Hadi, Koranhindi, Hulugho, Gal Magala, Gubis, Bodhai, Sangailu, Bulla, Golol and Garabey). The sampling frame used a margin error of 0.05% because of resource constraints. Such an error margin is reliable so long as the sample size is over 10% (Ehrlich and Edward, 1991). The sampling intensity was based on the distribution and density of human settlements within the eleven villages. Selection of respondents from the village was random and proportionately determined from the random tables. The District Statistics Officer, area Chiefs and elders were requested to provide information to enable the principal researcher to compile a comprehensive list of households in the area.

3.6.2 Sample size

The sample frame consisted of all the households resident in the 11 villages. An appropriate sample was obtained using the following formula (Kinuthia, 2005):

$$n = \frac{N}{1 + Ne^2}$$

Where: n = Sample size for the study area;

N = Total number of households in the area; and

e = Desired margin of error.

In each village, a random sampling technique was used to select the sample. The sample size was determined through proportional allocation depending on the total number of households in the village as shown in the formula below.

$$n_x = \frac{(N_x)(n)}{N}$$

Where n_x = Sample size for village (x);

N_x = Total number of households in village (x);

n = Sample size for the study area; and

N = Total number of households in the area

3.6.3 Target communities

This study researched Indigenous Knowledge Systems (IKS) in biodiversity conservation among the Boni and Somali communities. It focused primarily on traditional systems. The major focus of the indigenous knowledge systems study can thus be highlighted as:

i. To uncover the socio-political, religious, economic and environmental implications of indigenous knowledge systems to the local community;
ii. To identify and analyze the traditional methods of natural resources management;
iii. To assess the value and limitations of indigenous knowledge systems in current times;
iv. To identify methods through which indigenous knowledge systems can be incooporated in policy and decision making processes for development and conservation.

A total of 100 respondents were interviewed from the 11 villages. Each respondent was interviewed at their home location for both socioeconomic and forest interviews. The interviews were conducted in either English or Kiswahili, depending on the convenience of the respondent, and in many cases with the assistance of interpreters. Each interview lasted about one hour.

3.6.4 Interviews and focused group discussions

The field surveys sought to involve local communities in resource inventorying, based on the premise that participatory approaches to natural resource management lead to reduction in environmental degradation. Information was collected through personal interviews with farmers, site visits, group discussions, and the use of Village-Based Researchers (VBR). The VBRs prepared the community for the field study and facilitated discussions. The knowledge, views and interpretations of the participants were an integral part of the research which reflected ownership of the environmental knowledge and practices.

The questions were designed to explore various approaches through which environmental knowledge and skills were acquired, interpreted and disseminated (Appendix 1B). The knowledge and skills that needed to be observed, understood and documented were set in the social and cultural context of the indigenous communities so it was essential to understand the settings in which they occurred. Phase two of the research was therefore exploratory in nature and had to be located within the natural settings where the participants would feel safe and valued. Questionnaires were also designed around the understanding that natural ecosystems provide us with a range of services including the production of clean water and the control of climate, on which human lives depend.

The questionnaires comprised of structured and open-ended interviews for individual respondents. The structured questions allowed the researcher to exercise control over the interview process in guiding the respondent within a given focus or theme and also allowed for statistical analysis. The open-ended questions allowed the interviewees freedom of expressing themselves fully whenever they chose adding to the qualitative value of the data.

The questionnaire, besides containing questions to establish the socio economic status of the two communities and the perceived threat level to the forest, was designed along the following thematic groups in order to find out the indigenous knowledge systems used for conservation of biodiversity and utilization of plant species in Ijara Sub County: i). Land husbandry ii) Plant breeding iii) Animal breeding iv) Drought and flood monitoring & predictions v) Making rain vi) Water management vii) Traditional medicine viii) Gathering of wild food ix) Environmental conservation x) Classification systems for plants, animals, soils, water and weather; empirical knowledge about flora, fauna and inanimate resources and their practical uses.

The third type of interview was the *focused group discussions,* whose questions were generated from the responses of structured and open-ended interviews, especially those that required extensive and collective deliberations. The focus group discussions comprised of a series of meetings to generate relevant information from selected individuals (those known to hold the knowledge of interest). In this case, these included village elders and Heads of Departments in Line Ministries, District Commissioner, selected opinion leaders in the community. Focus group interviews were also conducted with the young people to find out the level of dissemination of IKS from the old to the young.

3.7 Secondary Data

A desktop study was undertaken to identify the various natural resources in the study area. Other information was sourced from reports of relevant government departments/ministries that included National Environment Management Authority (NEMA), Kenya Forest Service (KFS); Kenya Wildlife Services (KWS); Ministry of Agriculture (MOA); Ministry of Water and Irrigation (MWI); Department of Remote Sensing and Resource Surveys (DRSRS); National Museums of Kenya (NMK) and Kenya Forestry Research Institute (KEFRI). Additional information was also collected from Private Sector, NGOs and CBOs. Relevant information was drawn from Internet search to gain insight on what has been done. Selected libraries including WB, UNEP, NEMA and local universities were also utilized. The information was used to build the literature review and also to augment the primary data.

3.8 Data Analysis

Prior to Advanced Data Analysis (ADA), an exhaustive Exploratory Data Analysis (EDA) was performed. The EDA involved the computing of traditional univariate and bivariate statistics and plotting of histograms, correlation matrices, and scattergrams. Although univariate and bivariate measures provide useful summaries, they do not describe all the spatial features of the data.

The ADA included regression analysis, Analysis of Variance (ANOVA), and Principal Component Analysis (PCA). All statistical analyses were performed using procedures contained in Statistical Packages for Social Sciences - SPSS (Release 6.0, SPSS Inc., 1989-1993), EXCEL (Microsoft ® Excel 1997) and SYSTAT (SYSTAT 5.03, SYSTAT inc., 1990-1993). Only those relationships exceeding the normal acceptable level of statistical significance at $p < 0.05$ were considered.

The Pearson correlation coefficient was used to measure how well one variable can be represented as a linear function of the other. This statistic can range from $^{-}1$ to $^{+}1$ depending on whether the variables are related linearly in a negative or positive manner (Rowntree 1981). Regression analysis was performed in order to model the kind and degree of relationships between morphometric, physico-chemical and biological variables. Multiple linear regression aims at explaining the values of a variable Y (dependent) by means of other variables X_1, X_2, …Xq (independent). The general model by which it is often postulated that the relationships are linear is represented as follows according to Chatterjee and Price (1991);

$Y_i = \beta_0 + \beta_1 X_{1I} + \beta_2 X_{2I} +, \ldots. + \beta_m X_{mi} + \varepsilon_1$

where Y_i is an estimate of the i^{th} dependent variable from the independent variables X_1, X_2, ….X_m, X_I is the i^{th} observation of the independent variable (partial regression coefficient), β_0 is the y-intercept (a regression constant), $\beta_i$is slope of the relationship between Y_I and X_I, and ε_1 is the error term for the i^{th} sample.

ANOVA (Clark & Hosking 1986) was used to compare the variation in values between transects for the forest characteristics and between years for the NDVI values. The ANOVA model can be summarized as follows:

$$\sum_i\sum_j(Y_{ij} - Y_g)^2 = \sum_i\sum_j(Y_{ij} - Y_j)^2 + \sum_{nj}(Y_j - Y_g)^2$$

where $\sum_i\sum_j(Y_{ij} - Y_g)^2$ is the Total Sum of Squares (SST), $\sum_i\sum_j(Y_{ij} - Y_j)^2$ is the Within Sum of Squares (SSW), and $\sum_{nj}(Y_j - Y_g)^2$ is the Between Sum of Squares (SSB).

The chi square (χ^2) test (Clark & Hosking 1986) was used to compare values recorded in different transects with the expected occurences. The (χ^2) test summarized as follows

$\sum\{(O - E)^2/E\}$

Where o is the observed value and e is the expected value for the hypothesis of no difference.

For non parametric data specifically on attitudes and values from IKS survey, the Kruskal Wallis test was used instead of ANOVA. Clark & Hosking (1986) explained that while ANOVA is used for discrete data, the Kruskal Wallis test is used for non parametric data ranks, attitudes, coded data and values. The Likert scale was used to rank attitudes among groups of people which were then analysed by the the Kruskal Wallis test which is calculated as follows

where:

- n_i = is the number of observations in group
- r_{ij} = is the rank (among all observations) of observation j from group i

- N =is the total number of observations across all groups

All the statistical tools used here were selected as a result of their good performance in other studies similar to the present one. Convenience and ease of implementation was also considered. One major drawback associated with some of the techniques was the fact that they generally assume that any one datum is independent of all other data and that the data are distributed identically which is rarely the case in ecological studies. During data analysis, outliers were identified using the Grubbs test (Grubbs & Beck, 1972). They were only removed after sufficient consideration and judgement.

CHAPTER FOUR:RESULTS

This chapter presents the findings of the research and seeks to comprehensively examine the research objectives, questions and hypotheses against these findings.

4.1 BONI FOREST PLANT SPECIES COMPOSITION

A total of 386 plant species both woody and habeceous, representing 81 families were recorded in the study. The complete checklist of the species in the forest is presented in Appendix 5. The vernacular names indicated in some of the subsequent tables were derived from respondents among the Boni and Somali communities and it can be noted that for some species there were no vernacular names while some species shared vernacular names.

The most dominant family in this forest was *Mimosaceae* with 12.4% of all species identified in the study belonging to this family (Table 4.1). The family *Mimosaceae* had a variety of members ranging from trees, woody shrubs to annuals. The second most dominant family was *Euphorbiaceae* which included the genus *Croton, Bridelia* and *Drypetes* among others. It had a species occurrence of 9.3% of the data for all plant families encountered in the study. The other important families included, *Rubiaceae*, the coffee family, *Combretaceae* and *Papilionaceae* accounting for 5.43%, 4.65% and 4.65% respectively of all the species recorded in the study area. Less common plant families included *Olacaceae, Icaceaceae, Rhamnaceae, Rhizophoraceae, Zamiaceae, Simaroubaceae, Verbanaceae* and *Zygophyllaceae* each of which had a species composition of less than 1% of all species recorded. Natural ecosystems provide a wide variety of plants that are important for traditional medicines and modern pharmaceutical products including enhancing ecosystem function. A total of 130 plant species identified were woody belonging to 52 families (Table 4.2). Most of these were from the families of Mimosaceae, Euphorbiaceae and Papilionaceae.

Table 4.1: Ranking the major plant families based on percentage dominance

Rank	Family	Percentage composition
1.	Mimosaceae	12.40
2.	Euphorbiaceae	9.30
3.	Rubiaceae	5.43
4.	Combretaceae	4.65
5.	Papilionaceae	4.65
6.	Sapindaceae	3.88
7.	Anacardiaceae	3.10
8.	Apocynaceae	3.10
9.	Caesalpinaceae	3.10
10.	Loganiaceae	3.10
11.	Sapotaceae	3.10
12.	Annonaceae	2.32
13.	Burseraceae	2.32
14.	Capparaceae	2.32
15.	Celastraceae	2.32
16.	Ebenaceae	2.32
17.	Sterculiaceae	2.32

Table 4.2: List of woody plant species identified in the study area

S/N	*Species name*	Family	Vernacular name
1	*Abutilon hirtum (Lamarck)*	Malvaceae	Matawi
2	*Acacia brevispica (Harms.)*	Mimosaceae	Furgorri
3	*Acacia bussei Harms*	Mimosaceae	Galol
4	*Acacia drepanolobium*	Mimosaceae	Galol
5	*Acacia elatior Brenan*	Mimosaceae	Burra
6	*Acacia mellifera (Vahl) Benth*	Mimosaceae	Bil-el
7	*Acacia nilotica (L.) Willd. ex Delile*	Mimosaceae	Tugerr
8	*Acacia reficiens Wawra*	Mimosaceae	Khansa
9	*Acacia robusta (Burch.)*	Mimosaceae	Not given
10	*Acacia senegal (L.) Willd. Syn*	Mimosaceae	Ethad-geri

11	*Acacia seyal Del.*	Mimosaceae	Fullai/JIKSh
12	*Acacia sieberiana var.woodii*	Mimosaceae	Chiak
13	*Acacia tortilis Hayne*	Mimosaceae	Kura
14	*Acacia volkensii*	Mimosaceae	Not given
15	*Acacia xanthophloea Benth.*	Mimosaceae	Fulai
16	*Adansonia digitata L.*	Bombacaceae	Jah/Yak
17	*Adenium obesum Forssk.*	Apocynaceae	Arba/Gochan-gol
18	*Afzelia quanzensis Welw.*	Caesalpinaceae	Bamba Kofi
19	*Allophylus petiolatus Radlk.*	Sapindaceae	Not given
20	*Apodytes dimidiata*	Icacinaceae	Mfreti
22	*Asteranthe asterias (S. Moore)*	Annonaceae	Mgagini
21	*Balanites aegyptiaca (L.) Del. (Hingot)*	Zygophyllaceae	Kullan
23	*Balanites wilsoniana Dawe & Sprague*	Zygophyllaceae	Kullan
24	*Borassus aethiopium Mart.*	Acanthaceae	Ong
25	*Boscia angustifolia A. Rich.*	Capparidaceae	Chieh
26	*Boscia tomentosa Toelken*	Capparaceae	Dosi
27	*Brachylaena huillensis O. Hoffm.*	Compositeae	Avud
28	*Bridelia cathartica G. Bertol*	Euphorbiaceae	Not given
29	*Buxus obtusiflolia (Mildbr.) Hutch*	Buxaceae	Not given
30	*Cadaba farinosa Forssk*	Capparaceae	Keunya
31	*Canthium bibracteatum (Baker) Hiern*	Rubiaceae	Natanna
32	*Canthium kilifiense (Bridson) Lantz*	Rubiaceae	Natanna
33	*Canthium pseudoverticillatum S.Moore*	Rubiaceae	Not given
34	*Capparis sepiaria (L.) R.Br.*	Capparaceae	Nothake
35	*Cassipourea euryoides Alston.*	Rhizophoraceae	Mkulangi
36	*Catunaregam nilotica (Staphf)*	Rubiaceae	Kokonya
37	*Cola minor Brenan*	Sterculiaceae	Not given
38	*Combretum constrictum (Benth)*	Combretaceae	Eddi shebei
39	*Combretum illairii Engl.*	Combretaceae	Not given
40	*Combretum schumannii Engl.*	Combretaceae	Mugurure
41	*Commiphora africana (A. Rich) Engl. Syn*	Burseraceae	Dabba'un'un

42	*Commiphora alata Chiov.*	Burseraceae	Danu
43	*Commiphora edulis (Klotzsch) Eng*	Burseraceae	DabarrIKS
44	*Craibia brevicaudata (Vatke) Dunn*	Papilionaceae	Not given
45	*Crotalaria madurensis Wight & Arn*	Papilionaceae	Not given
46	*Croton megalocarpus Hutch.*	Euphorbiaceae	Gobole/Xobole
47	*Croton polytrichus Pax*	Euphorbiaceae	Not given
48	*Croton pseudopulchellus Pax.*	Euphorbiaceae	Barranad
49	*Croton talaeporos Radcl.*	Euphorbiaceae	Barranad
50	*Cussonia zimmermannii Harms*	Araliaceae	Not given
51	*Dalbergia melanoxylon Guill. et Perrott.*	Papilionaceae	Deidei
52	*Dalbergia vacciniifolia Vatke*	Papilionaceae	Not given
53	*Dialium orientale Bak. f.*	Caesalpinaceae	Samachi/Sheshubla
54	*Dicrostaechys cinerea*	Boranginaceae	Msativu/Ditar
55	*Diospyros consolatae Chiov.*	Ebenaceae	Not given
56	*Diospyros cornii Chiov.*	Ebenaceae	Goma-gumuh
57	*Dobera glabra Forssk.*	Salvadoraceae	Hurub
58	*Drypetes natalensis (Harv.) Hutch*	Euphorbiaceae	Katodon
59	*Ehretia bakeri Britten*	Boranginaceae	Keruki
60	*Ekebergia capensis Sparrm.*	Meliaceae	Not given
61	*Encephalartos hildebrandtii A.Braun*	Zamiaceae	Not given
63	*Erythrina sacleuxii Hua*	Papilionaceae	Vugu
62	*Erythrophleum suaveolens (Guill. & Perr.)*	Caesalpinaceae	Kina
64	*Euclea natalensis A.DC.*	Ebenaceae	Not given
65	*Euphorbia candelubrum Kotschy*	Euphorbiaceae	baraidi/Darkhen
66	*Euphorbia cuneata Vahl*	Euphorbiaceae	Darkhen
67	*Excoecaria bussei Pax*	Euphorbiaceae	Not given
68	*Garcinia livingstonei Anders*	Clusiaceae	Chan-farod
69	*Garcinia volkensii Engl*	Clusiaceae	Mangales
70	*Gardenia volkensii K.Schum*	Rubiaceae	Kurkoi
71	*Grewia plagiophylla K. Schum*	Tiliaceae	Bebhi
72	*Grewia stuhlmannii K.Schum.*	Tiliaceae	Da'bi

74	*Haplocoelum foliolosum (Hiern) Bullock*	Sapindaceae	Tokohoji
75	*Haplocoelum inoploeum Radlk.*	Sapindaceae	Gogiza
76	*Harrisonia abyssinica Oliv.*	Simaroubaceae	Sabuni
77	*Homalium abdessamadii Aschers. & Schweinf*	Euphorbiaceae	Not given
78	*Hunteria zeylanica (Retz.) Gardener ex Thw*	Apocynaceae	Ndani
73	*Hyphaene compressa H. Wendl.*	Arecaceae	Ornica/Barr
79	*Hyphaene coriacea Gaertn*	Arecaceae	Medi
80	*Inhambanella henriques*	Sapotaceae	Not given
81	*Kigelia africana (Lam.)*	Bignoniaceae	Shelole/Bokorola
82	*Kraussia kirkii (Hook.f.) Bullock*	Rubiaceae	Den
83	*Lannea alata (Engl.) Engl.*	Anacardiaceae	den
84	*Lannea schweinfurthii (Engl.) Engl.*	Anacardiaceae	Den
85	*Lannea stuhlmannii (Engl.) Engl.*	Anacardiaceae	Wahari
86	*Lannea welwitschii (Hiern) Engl*	Anacardiaceae	Not given
87	*Lawsonia inermis Linn.*	Lythraceae	Komochi/Allan
88	*Lecaniodiscus fraxinifolius Baker.*	Sapindaceae	Chanah
89	*Lonchocarpus bussei Harms*	Papilionaceae	Ina-eh-leh
90	*Majidea zanguebarica Kirk ex D. Oliver*	Sapindaceae	Not given
91	*Manilkara mochisia (Baker) Dubard*	Sapotaceae	Not given
92	*Manilkara sulcata (Engl.) Dubard*	Sapotaceae	Kurag
93	*Maytenus mossambicensis Klotzsch Blakelock*	Celastraceae	Not given
94	*Maytenus undata Thunb. Blakelock*	Celastraceae	Not given
95	*Moringa stenopetala (Baker f.) Cufodontis*	Moringaceae	Safara
96	*Mystroxylon, aethiopicum, (Thunb.)*	Acanthaceae	Not given
97	*Nectaropetalum kaessneri Engl*	Erythroxylaceae	Not given
98	*Newtonia erlangeri (Harms) Brenan*	Mimosaceae	Tuari
99	*Newtonia hildebrandtii (Vatke) Torre*	Mimosaceae	Not given
100	*Ochna thomasiana Engl. & Gilg*	Ochnaceae	Not given

101	*Oldfieldia somalensis Chiov. Milne-Redh.*	Euphorbiaceae	Mbauri
102	*Ormocarpum kirkii S. Moore*	Pappilionaceae	Mpotsho ndovu
103	*Rauvolfia mombasiana Stapf*	Apocynaceae	Not given
104	*Rinorea ilicifolia (Welw. ex Oliv.)*	Violaceae	Bullabula
105	*Salacia madagascariensis (Lam.) DC.*	Celastraceae	Not given
106	*Salvadora persica L.*	Salvadoraceae	Ade
107	*Sideroxyylon inerme Baker*	Sapotaceae	Not given
108	*Sterculia africana Lour.*	Sterculiaceae	darab/Garanre
109	*Sterculia appendiculata K.Schum*	Sterculiaceae	Darab
110	*Strychnos decussata Pappe Gilg*	Loganiaceae	Not given
111	*Strychnos henningsii Gilg*	Loganiaceae	Not given
112	*Strychnos madagascariensi*	Loganiaceae	Korie
113	*Strychnos spinosa Lam.*	Loganiaceae	Mangula
114	*Suregada zanzibariensis Baill*	Euphorbiaceae	Balmut
115	*Synsepalum subverticillatum Bruce &Penn*	Sapotaceae	Not given
116	*Tabernaemontana elegans Stapf.*	Apocynaceae	Yamoozi
117	*Tamarindus indica L. Tamarindo.*	Caesalpinaceae	Mukai
118	*Tarenna graveolens (S.Moore)*	Rubiaceae	Gelai
119	*Teclea nobilis Del.*	Rutaceae	Not given
120	*Teclea trichocarpa (Engl.) Engl*	Rutaceae	Not given
121	*Terminalia cuneata Roth.*	Combretaceae	Leh-heli
122	*Terminalia prunioides Lawson*	Combretaceae	Not given
123	*Terminalia superba Engl. et Diels*	Combretaceae	Mbabare
124	*Thespesia danis Oliv.*	Malpighiaceae	Mlambale
125	*Uvaria acuminata Oliv.*	Annonaceae	Halas/Kaphan
126	*Uvaria denhardtiana Engl. & Diels*	Annonaceae	Tomorr
127	*Vitex ferruginea Schumach. & Thonn.*	Verbenaceae.	Mkaligote
128	*Warburgia stuhlmannii Engl.*	Canellaceae.	Not given
129	*Ximenia americana L.*	Olacaceae	Not given
130	*Ziziphus mauritiana Lam.*	Ramnaceae	Not given

4.2 Species Diversity, Abundance and Similarity Indices

The diversity of species present in an ecosystem can be used as one gauge of the health of an ecosystem. Species richness is a measure of the number of different species present in an ecosystem, while species evenness measures the relative abundance of the various populations present in an ecosystem. Comparison of the diversity index with that of other areas provides insights into the species diversity and the health of the ecosystem. The diversity index used was the Shannon Diversity Index. The species richness of the forest as indicated by the number of species recorded per transect showed that Transect 1 (in Mararani area in Boni Forest Reserve) had the highest species richness with 109 species. This was followed by Transect 2 (in Mangai location) with 97 and Transect 4 (in Sankuri location) with 83 species. All these transects (1, 2 and 4) were located on the southern part of the study area. Transect 6 (in Sangailu location) had the lowest richness with 41 species (Table 4.3). The diversity of species in each of the transects (Table 4.3) calculated from the Shannon Wiener Diversity index, indicated that Transect 1 had the highest diversity (3.69) closely followed by Transect 2 (3.66) while Transect 6 had the lowest (2.38, Table 4.3). The study noted that species richness and diversity decreases northwards, which coincides with rainfall decrease and where Acacia-commiphora woodland dominates.

Table 4.3: Species richness by numbers and the Shannon Wiener Diversity index

Transect	Area	Species counted	Shannon Wiener Diversity index
1	Mararani	109	3.69
2	Mangai	97	3.66
3	Bodhai	83	3.34
4	Sankuri	70	3.19
5	Hulugho	55	3.15
6	Sangailu	41	2.38

4.3 SORENSON'S SPECIES SIMILARITY INDEX AMONG TRANSECTS

Biological diversity, within an ecological context, is the different type of species and their abundances at a given scale. There are many different ways to measure biological diversity, and at different spatial scales. Comparative analysis of woody species characteristics between transects was undertaken using Sorenson's index and the results are shown in Table 4.4. The species of the southern parts of the study area which have characteristics of coastal forests (Transect 1, 2 and 4) have greater similarity indicated by 83%, 82% and 88% in comparison among them but these species have low similarity compared to those of the northern part of the study area. For example, there was only 44% similarity between transect 1 and 5. On the other hand species similarity among study areas in the northern part was high. For example, transect 5 and 6 had a species similarity index of 88%.

Table 4.4: Sorenson's species similarity index among transect

Comparisons	**1st Transect**	**2nd Transect**	**Similar Species**	**Sorenson's Index**
Transect 1 vs transect 2	109	97	73	0.83
Transect 1 vs transect 3	109	83	25	0.41
Transect 1 vs transect 4	109	70	62	0.82
Transect 1 vs transect 5	109	55	23	0.44
Transect 1 vs transect 6	109	41	25	0.50
Transect 2 vs transect 3	97	83	26	0.45
Transect 2 vs transect 4	97	70	65	0.88
Transect 2 vs transect 5	97	55	23	0.46
Transect 2 vs transect 6	97	41	20	0.45
Transect 3 vs transect 4	83	70	25	0.49
Transect 3 vs transect 5	83	55	51	0.85
Transect 3 vs transect 6	83	41	48	0.87
Transect 4 vs transect 5	55	55	41	0.85
Transect 4 vs transect 6	55	41	21	0.61
Transect 5 vs transect 6	41	41	32	0.88

NB: 1st and 2nd Transect refer to the transects compared in Column 1

4.4 Species Dominance by Abundance, Frequency and Basal Area

4.4.1 Species relative abundance

To identify which species dominated at different sites, dominance indices were recorded in terms of number of individuals of a species, basal area, crown cover and height. Ten most dominant species were identified based on their numbers in the specific transects as shown in Table 4.5 below. The full names of the species codes used are given in Appendix 3. In transect one, *C. pseudopulchellus* had the highest relative abundance (14.4) followed by *C. brevispiaca* (10.5), *N. hildebrandtii* (6.3) and *C. africana* (4.4). In transect 2, *C. pseudopulchellus* again had the highest relative abundance (23.6) followed again by *C. brevispiaca* (7.6), *D. cornii* (6.5) and *B. huillensis* (5.6). Transect 3 recorded *T. danis* (19.8) as the highest, followed by *D. cornii* (8.2), *G. plagiophylla* (8.1). In transect 4,*C. pseudopulchellus* again had the highest relative abundance at 11.4, followed by *C. nilotica* (9.3) and *M. sulcata* (5.5). In transect 5, the species with the highest relative abundance was *A. nilotica* (10.5), followed by *B. tomentosa* (9.4), T. *graveolens* (8.3), *C. constrictum* at 8.1 and *A. reficiens* at 7.4. In transect 6, *A. reficiens* recorded the highest relative abundance at 36.1 which is the highest recorded in all the transects, followed by *D. glabra* at 12.0, *T. danis* 11.6, *A. nilotica* 8.6 and *A. seyal* 6.9. The study observed that *Croton pseudopulchellus* was the most abundant species in 3 transects (1, 2 and 4), which were also the highest biodiversity transects (cf section 4.2). In transect 2, this highly branched shrubby tree accounted for 23.6% of the trees recorded, colonizing the area by having very many individuals. However, *C. pseudopulchellus* did not occur in transect 3, 5 and 6. Other commonly found species in the area were *C. nilotica*, *A. nilotica*, *D. cornii*, *D. glabra* and *T. danis* all of which appear in at least 4 of the six transects. *C. brevispiaca* had 10.5% relative abundance in transect 1, 7.6% in transect 2 and did not occur in any of the other transects. Transect 6 recorded a very high relative abundance of *A. reficiens* (36%), 8.6% *A. nilotica*, 6.9% *A. seyal* and 2.7% *A. bussei*. *A. seyal* occurred in transect 2 also albeit at low relative abundance (4.0%). The species with the lowest relative abundance include *H. zeylanica* (2%) in transect 1, *D. glabra* (2.6%) in transect 2, *S. persica* (3.1%) in transect 3, *L. stuhlmanii* (2.9%) in transect 4, *O. thomasiana* (3.3%) in transect 5 and *S. persica* (1.4%) in transect 6.

Table 4.5: Species ranking based on relative abundance (%) among transects

Rank	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Transect 6
1	*C. pseudopulchellus* 14.4	*C. pseudopulchellus* 23.6	*T. danis* 19.8	*C. pseudopulchellus* 11.4	*A. nilotica* 10.5	*A. reficiens* 36.1
2	*C. brevispiaca* 10.5	*C. brevispiaca* 7.6	*D. Corniii* 8.2	*C. nilotica* 9.3	*B. tomentosa* 9.4	*D. glabra* 12.0
3	*N. hildebrandtii* 6.3	*D. cornii* 6.5	*G. plagiophylla* 8.1	*M. sulcata* 5.5	*T. graveolens* 8.3	*T. danis* 11.6
4	*C. Africana* 4.4	*B. huillensis* 5.6	*C. nilotica* 6.9	*C. africana* 5.4	*C. constcritum* 8.1	*A. nilotica* 8.6
5	*C. nilotica* 3.9	*C. euryoides* 4.9	*T. spinosa* 6.1	*C. bibracteatum* 5.2	*A. reficiense* 7.4	*A. seyal* 6.9
6	*D. cornii* 3.9	*N. hildebrandtii* 4.8	*D melanoxylon* 5.7	*T. danis* 4.2	*M. sulcata* 7.0	*C. euryoides* 3.7
7	*M. zanguebarica* 3.7	*C. africana* 4.6	*L. scweinfurthii* 4.5	*D. cornii* 4.1	*D. glabra* 6.9	*A. bussei* 2.7
8	*B. huillensis* 3.5	*A. seyal* 4.0	*D. glabra* 4.4	*N. erlangeri* 4.1	*C. nilotica* 4.1	*C. illairii* 2.1
9	*C. euryoides* 2.1	*C. nilotica* 2.7	*A. nilotica* 4.1	*A. nilotica* 2.9	*T. danis* 3.9	*C. constcritum* 1.7
10	*H. zeylanica* 2.0	*D. glabra* 2.6	*S. persica* 3.1	*L. stuhlmanii* 2.9	*O. thomasiana* 3.3	*S. persica* 1.4

4.4.2 Species relative dominance by basal area

Basal area, as measured at breast height is a useful indicator of forest canopy cover as the two parameters have a positive correlation. In the study, it thus served to indicate the dominance of specific tree species within Boni Forest. In transect 1,*N. erlangeri* had 51.3% basal area, followed by *A. nilotica* with 31.7% and *D. cornii* with 9.1% (Table 4.6). Transect 2 recorded *N. hildebrandtii* at 19.1% as having the highest basal area, followed by *D. cornii* (18.6%) and *A. digitata* (11.7%). In transect 3, *L. scweinfurthii* had 50.1% basal area and was the highest, followed by *D. cornii* at 18.3%, and *T. spinosa* at 7.1%. In transect 4,*A. digitata* recorded a large basal area of 31.4%, followed by *D. cornii* at 17.6%, *N.hildebrandtii* at 6.1%.

The study observed that in transect 4, *Adansonia digitata* also recorded a basal area of 5.2% which implies some exaggerated basal area in some of its species. In transect 5, *D. glabra* was the highest with 45.9% basal area, followed by *B. tomentosa* at 17.9%, and *S. persica* at 7.2%. In transect 6, the species with the highest basal area was *D. glabra* at 53.3%, followed by *D. cornii* at 8.8% and *M. mochisia* at 6.5%. Different species dominated at different sites and it was only *D. glabra* that dominated in two transects (5 and 6 respectively). In transect 1, *N. erlangeri* (51.3%), in transect 2, *N. hildebrandtii* (19.1%) and in transect 3 *L. scweinfurthii* (50.1%) were ranked highest. *A. digitata* and *D. cornii* were dominant trees in all the transects. Other dominant trees included *D. glabra*, *A. nilotica* and *S. persica* which occurred at least in three transects. In each transect, there was one dominant species or two co-dominating species, and then a fair distribution of basal areas among a number of tree species.

There were few very deformed trees that accounted for exaggerated basal areas. Such very deformed trees had higher diameters that influenced their relative dominance values. They included *N. erlangeri* recorded in Transect 1, *L. scweinfurthii* recorded in Transect 3 and *D. glabra* recorded in Transect 5 and 6. Transect 2 had a fair distribution of species and there was no clearly dominant species.

Table 4.6: Species ranking based on % basal area among transects

Rank	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Transect 6
1	*N. erlangeri* 51.3	*N. hildebrandtii* 19.1	*L. scweinfurthii* 50.1	*A. digitata* 31.4	*D. glabra* 45.9	*D. glabra* 53.3
2	*A. nilotica* 31.7	*D. cornii* 18.6	*D. cornii* 18.3	*D. cornii* 17.6	*B. tomentosa* 17.9	*D. cornii* 8.8
3	*D.cornii* 9.1	*A. digitata* 11.7	*T. spinosa* 7.1	*N. hildebrandtii* 6.1	*S. persica* 7.2	*M.mochisia* 6.5
4	*T. Danis* 3.3	*B. aegyptiaca* 6.4	*D. glabra* 6.6	*A. digitata* 5.2	*A. nilotica* 5.5	*B. tomentosa* 4.9
5	*B aegyptiaca* 0.7	*B. huillensis* 4.7	*D melanoxylon* 2.3	*L. stuhlmanii* 4.9	*L. scweinfurthii* 3.4	*A. seyal* 4.1
6	*A. digitata* 0.5	*S. capensis* 3.7	*T. danis* 2.2	*D. glabra* 4.6	*D. cornii* 3.3	*A. reficiense* 3.4
7	*B. huillensis* 0.4	*A.quanzensis* 3.6	*M. mochisia* 1.8	*A. nilotica* 3.6	*M. sulcata* 3.0	*A. nilotica* 3.4
8	*N. hildebrandtii* 0.3	*B. wilsoniana* 3.3	*C. nilotica* 1.4	*L. stuhlmanii* 3.4	*C. edulis* 1.9	*C. constrictum* 3.1
9	*B. huillensis* 0.2	*C. schumanii* 2.85	*S. persica* 1.19	*O. somalensis* 2.16	*B. angustifolia* 1.96	*A. bussei* 2.2
10	*M. sulcata* 0.1	*O. somalensis* 2.5	*D. orientalis* 1.1	*S. africana* 1.7	*S. madagascariensis* 1.5	*S. persica* 2.1

The findings of basal area among transects shows that transect 4, (Sankuri) had the highest basal area (m^2ha^{-1}), followed by transect 2, (Mangai) at 32.24 (m^2ha^{-1}), transect 1 (Mararani) at 26.56 (m^2ha^{-1}) and transect 3 (Bodhai) at 22.05 (m^2ha^{-1}) (Table 4.7). The least basal area was found in transects 5 (Hulugho) and 6 (Sangailu) at 9.15 (m^2ha^{-1}) and 10.77 (m^2ha^{-1}) respectively. The transects may have had numerous plant species but with very small basal areas as shown by the individual basal areas.

Table 4.7: Basal area among transects

Transect	Study area	Basal area (m^2ha^{-1})
Transect 1	Mararani	26.56
Transect 2	Mangai	32.24
Transect 3	Bodhai	22.05
Transect 4	Sankuri	36.75
Transect 5	Hulugho	9.15
Transect 6	Sangailu	10.77

4.4.3 Species dominance by crown cover

The crown size of trees in a forest correlates strongly with what can be considered as the healthy growth of the trees. The ranking of trees based on percentage crown cover in each of the transects showed that specific species dominated at specific study locations (Table 4.8). In transects 1 and 3, a tree of the species *L.scweinfurthii* was the highest ranked while in transects 2, 4, 5 and 6 the highest ranked trees were *B. huilensis*, *M. sulcata*, *A nilotica* and *C. constrictum respectively.* Among the best 10 ranked trees, transect 2 had four individuals of *N. hildebrandtii* while transect 5 had four individuals of *D. cornii*.

Results of crown dominance (Table 4.8) unlike those of basal area indicated that no one tree or species took a large portion of the forest crown. The 10 best ranked trees contributed a maximum of 20.22% (in transect 2) of the total crown cover in the forest, which was the highest compared to 9.04% in transect 4. This indicates that in transect 6, crown cover is distributed among many trees and the trees do not have very wide crowns (8.7%).

Some of the trees that were well ranked in terms of basal area were also ranked highly in terms of of dominance by crown cover. These included *N. erlangeri* in transect 1, *L. scweinfurthii* in transect 3, *A digitata* in transect 4 and *A nilotica* in transect 5.

Table 4.8: Ten most dominant individual trees by % crown cover

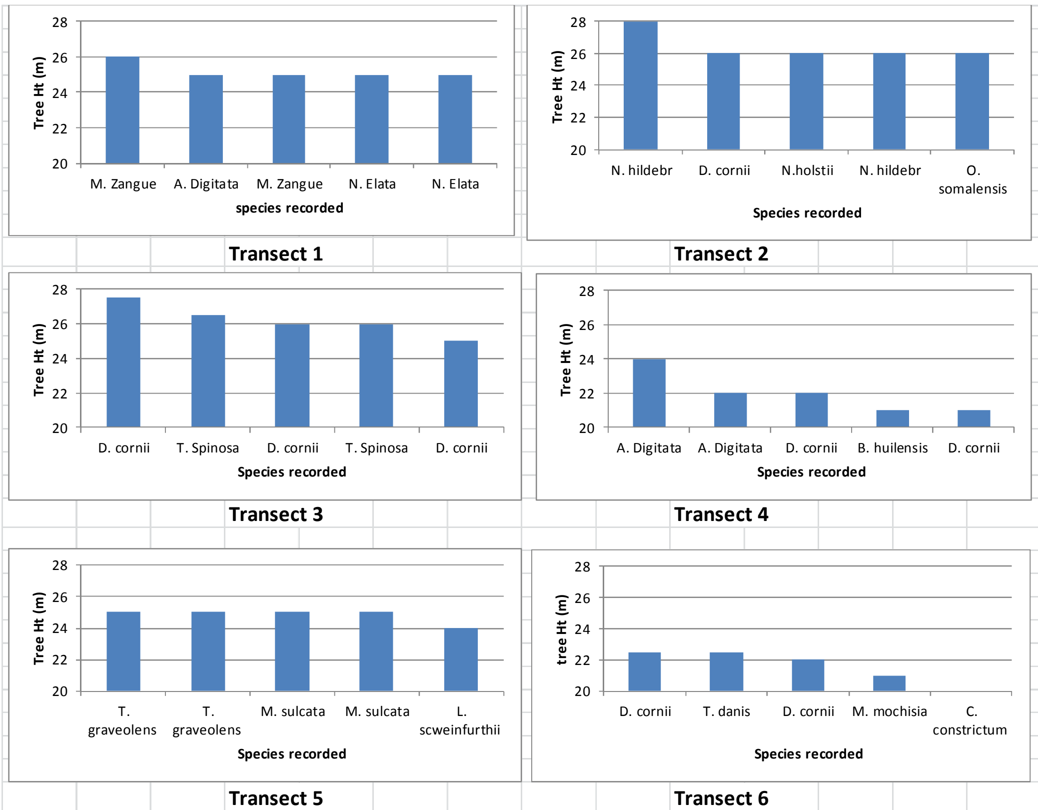
Rank	**Transect 1**	**Transect 2**	**Transect 3**	**Transect 4**	**Transect 5**	**Transect 6**
1	*L. scweinfurthii* 2.0	*B. huillensis* 2.2	*L. scweinfurthii* 1.5	*M. sulcata* 1.4	*A. nilotica* 1.8	*C. conscritum* 0.9
2	*B. aegyptiaca* 1.6	*A. quanzensis* 2.15	*A. nilotica* 1.4	*A. digitata* 1.4	*D. glabra* 1.7	*A. bussei* 0.9
3	*N. erlangeri* 1.6	*B. wilsoniana* 2.10	*D. cornii* 1.4	*A. digitata* 1.3	*A. nilotica* 1.5	*A. seyal* 0.9
4	*A. quanzensis* 1.6	*A. quanzensis* 2.1	*D. cornii* 1.4	*N. hildebrandtii* 1.2	*L. scweinfurthii* 1.5	*M. mochisia* 0.9
5	*D. glabra* 1.6	*N. hildebrandtii* 2.0	*T. spinosa* 1.3	*A. Digitata* 1.2	*D. glabra* 1.4	*A. nilotica* 0.9
6	*N. elatii* 1.5	*N. hildebrandtii* 2.0	*D. orientalis* 1.3	*A. nilotica* 1.2	*D. glabra* 1.3	*A. mellifera* 0.9
7	*L. scweinfurthii* 1.4	*A. quanzensis* 1.9	*D. cornii* 1.2	*D. glabra* 1.0	*A. nilotica* 1.3	*A. nilotica* 0.9
8	*A. quanzensis* 1.4	*A. quanzensis* 1.9	*D. cornii* 1.2	*L. scweinfurthii* 1.0	*L. scweinfurthii* 1.3	*C. constrictum* 0.9
9	*A. tortilis* 1.4	*N. hildebrandtii* 1.8	*T. spinosa* 1.2	*D. cornii* 0.9	*D. glabra* 1.3	*T. spinosa* 0.8
10	*A. digitata* 1.4	*N. hildebrandtii* 1.7	*T. spinosa* 1.2	*N. hildebrandtii* 0.9	*D. cornii* 1.2	*A. bussei* 0.7
Total						

4.4.4 Species dominance by height

The dominance of trees by height which identified emergents (trees whose crowns were lying above the rest) was compared among the different study locations as shown in Figure 4.1. The results showed that trees of different species dominated in different transects. In transect 1, *Majidaea zanguebarica* had two individuals among the tallest 5 tree species. Transect 2 was dominated by *N. hildebrandtii*, transect 3 by *T. spinosa*, transect 4 by *A. digitata*, transect 5 by *T. graveolens* and transect 6 by *D. cornii*.

The tallest trees encountered in the study had a height of 25m. Trees of transect 1, 2 and 3 had significantly taller trees than in the other transects as seen in Figure 4.1. An ANOVA test indicated a significant difference exists ($P<0.0005$) in the heights of 10 top canopy tree species among the transects. Transect 6 had shorter trees which could be associated to the type of vegetation in the drier areas of the study area.

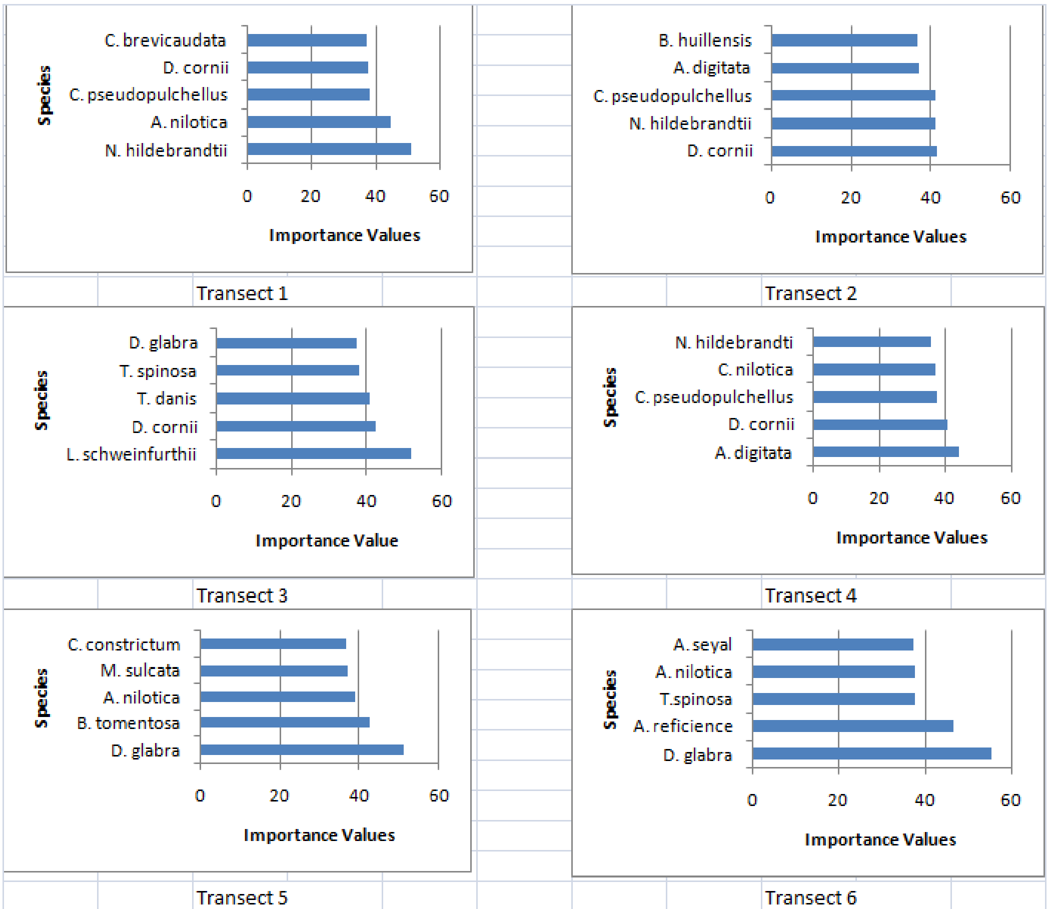
Figure 4.1: A comparison of height for the 5 top canopy trees in the transects



4.5 TREE SPECIES IMPORTANCE VALUES

By combining values of species dominance by basal area, species dominance by relative abundance and species dominance by frequency of occurrence among sample sites in a transect, the species were ranked to show species importance values. Figure 4.2 shows the best ranked 5 species in each transect.

Figure 4.2: Species overall dominance by importance values in all the transects



4.6 TREE DENSITIES AMONG THE DIFFERENT TRANSECTS

Tree density (No. of individuals ha-^{1}) varied widely across the study area as shown in Figure 4.3. Woody species density ranged between 572 individuals ha^{-1} in transect 6 to 1071 individuals ha^{-1} in transect 2. Transect 1 had a moderate distribution of trees among the canopies; 253 and 387 for top and low canopy respectively. The case was quite different for transetcs 3 and 6 where the difference between the top and low canopy was statistically significant by a χ^2test (P<0.05). Similarly, there was a significant difference (by χ^2 at P<0.05) in the number of individuals of woody species among the transects with a lower mean in Transect 5 and 6 which are in the drier zones and a significantly higher mean in the transects of the southern forests.

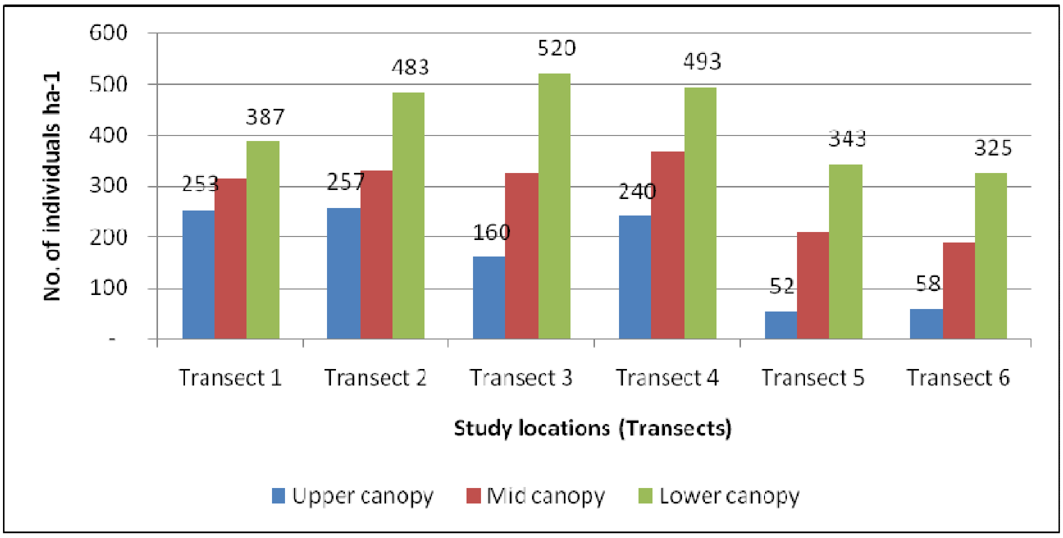


Figure 4.3: Tree densities among the different transects

The researcher observed huge trees in the forest comprising mainly of the following species: *Brachylaena huilensis* (Aworzi, Avud), *Steculia appendiculata* (Munyangatta), *Newtonia hildebrandtii* (Muwarale), *Neosogodonia africana* (Papano), *Manilkara mochisia* (Muwarade), *Carpodiptera africana* (Mlange), *Mimusops obtusifolia* (Kolati), *Oldfieldia somalensis* (Mbambara mbauri), *Haplocoeleum inopleum* (Tokohaji), *Dalbergia melanoxylon* (Samachi), *Diospyros conii* (Kolati gurati), *Diospyros abyssinica* (Motya-mowgi), *Terminalia spinosa* (Hareri), *Adansonia digitata* (Yak, Jah), *Lonchocarpus bussei* (Ina-eh-leh), *Tamarindus indica* (Morhoqa).

4.7 TREE VERTICAL STRUCTURE CURVES

In terms of the vertical structure (Figure 4.4), forests of southern Ijara (transect, 1, 2, 3 and 4) had moderate reverse J curves as compared to those of the drier north. For example the exponential factors for the curves in transect 1 and 2 were 0.211 and 0.34 respectively compared to 0.86 and 0.943 in the curves of transects 6 and 5 respectively.

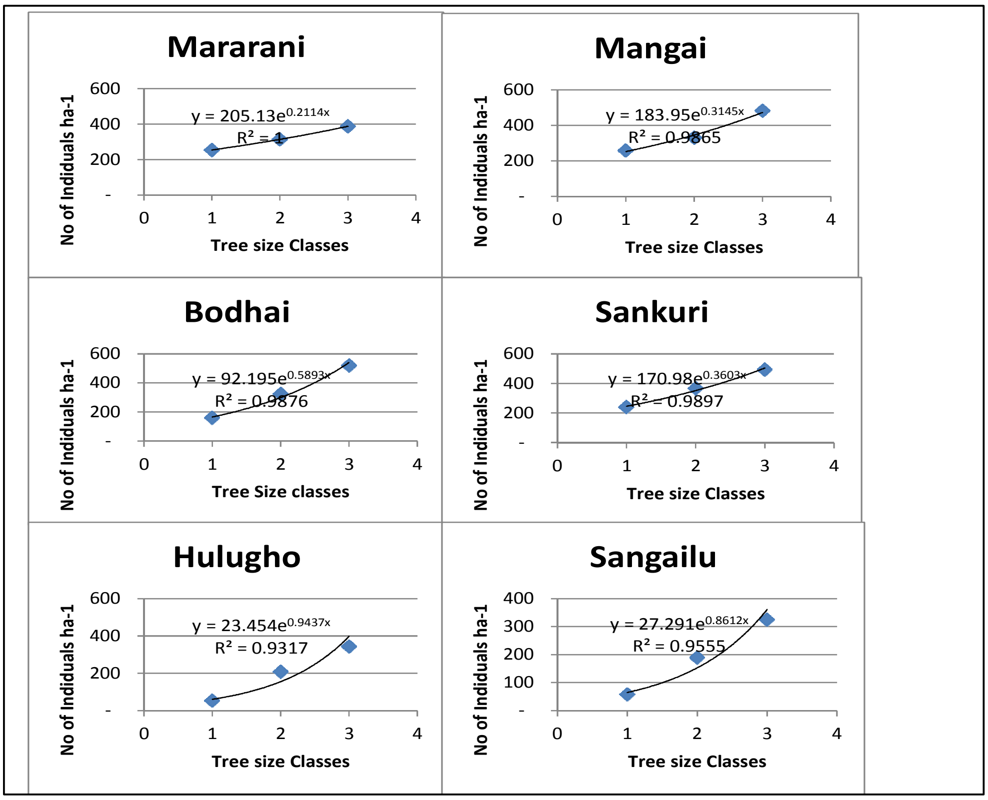


Figure 4.4: Reverse J curves for numbers of trees per size class

4.8 THREATS ON FOREST ENVIRONMENT

This section presents the findings on threats to the forest environment that were identified during the entire duration of the study. A scrutiny of human activities and their possible contribution to forest degradation was documented. The results also include an identification of potential threats to biological diversity.

4.8.1 Findings from the transect walk

The results presented in Table 4.9 were gathered during the transect walk. It was noted that in the south the Boni have embraced farming having settled near the boundary of the reserve which is 6 km from the junction to Kiunga track. A number of the Boni have settled right inside the Forest posing severe and significant threat to the forest.

Table 4.9: Threats to the forest resource

Transect	**Main causes of tree/forest destruction**
Mararani	a) Illegal logging and poaching with priority trees being exploited.
	b) There was some destruction because of the big population of elephants evidenced by felling trees and debarking
	c) Poor enforcement of laws for forest protection
	d) Grazing mainly by wild life
Mangai	a) Establishment of settlements in the forest (clearing large chunks of the forest)
	b) Forest fragmentation
	c) Some trees debarked by elephants
	d) Overgrazing
	e) Slash and burn farming technologies are practiced.
	f) Fire used to clear vegetation is at times uncontrollable causing more damage. g) Pit sawing and illegal harvesting noted. Target trees *T. spinosa and A quanzensis*
Bodhai	a) Forest fragmentation and settlements in the forest
	b) The expansion of agricultural activities to improve food security.
	c) Trees were being cleared and irrigation along the River Tana expanded.
	d) Priority timber species are most targeted (Good evidence of human destruction including illegal logging targeting *T. spinosa and A quanzensis)*
	e) Overgrazing
	f) Honey harvesting was common and in some cases involved felling trees
	g) Biodiversity of ecosystem confirmed from the variety of ant hills and a lot of litter (potential for forest fires)
Sankuri	a) Illegal logging of some vulnerable species like *B. huilensis and T spinosa*
	b) Forest fragmentation

	c) Poor enforcement of conservation laws d) Wildlife damage (A lot of dead wood identified and associated with elephant damage)
Hulugho	a) Clearance of vegetation.
	b) Cutting of trees mainly for construction (Many trees cut for construction with evidence of new settlements), preferred species; *D. glabra, A. nilotica, A. reficiens, T. danis,*
	c) Overgrazing that loosens the soil and makes it easily erodible Some areas were prone to flooding Evidence of animal bones indicate starvation due to drought d) Some trees debarked for medicinal purposes
Sangailu	a) Clearance of vegetation.
	b) Cutting of trees mainly for construction (Many trees cut for construction due to influx of communities), preferred species; *A. reficiens, A, bussei, B. angustifolia, T danis, Combretum spp*.
	c) Overgrazing that loosened the soil and made it easily erodible (Evidence that overgrazing by livestock caused soil erosion).

4.8.2 Findings from belt transects

The study found that forest environmental threats were on the rise and had potential to become numerous and widespread. Grazing in the forest interior by cattle was mainly during the drought periods. Wild animals such as Buffaloes were noted to be major grazers as evidenced by the dung and prints that were observed. Alot of burning, both recent and old was noted including 16 trees burnt earlier at one site. *Brachylaeniahuillensis* cut for honey extraction was a common phenomenon. In some areas no threats were observed, except the presence of a lot of dead wood which was a potential threat due to fire. High percentage litter cover could have been as a result of many species being deciduous. There was a lot of undergrowth of lianas in some sites that made it very difficult to penetrate the forest. For example, *Sterculia* was observed, the thickets making the forest impenetrable. Many ant hills were observed in certain sites. Table 4.10shows the threats identified

Significant changes affecting the forest area were conversions of forestland for agricultural use and settlements (which proved to be an acute environmental threat), deforestation, forest fragmentation and increased numbers of structures, such as houses. Income generating structures such as ecotourism initiatives built in the forest will in the long run become significant threats especially when access to the area becomes easy. The study was particulary concerned about the ecotourism efforts under the ALRM Project such as the tented camp that is already in use and other planned facilities that if not reviewed and activities guided through feasibility studies and strategic environment assessments may cause more harm than social good both ecologically and socially.

Table 4.10: Threats identified in Boni Forest

Item	Threat	Reason	Result
	Clearing the forest by pit sawing (Illegal tree harvesting), Illegal removal of building poles/ pole cutting, extracting wood for wood carving, (Unsustainable utilization patterns)	Socio-economic gains	Deforestation
	Slash and burn farming techniques to clear forest area	Short term economic benefits. The race to produce cash crops such as fruit, maize and beans	Deforestation
	Untested government policies Illegal settlements	Clearing the forest to make roads; Clearing the forest to settle the Boni & Somali in villages; Clearing the forest to introduce agriculture/cultivation. Used for urban and construction purposes The cutting down of trees for timber that is used for building materials, furniture, and paper products. Forests are also cleared in order to accommodate expanding population needs.	Deforestation
	Honey harvesting	Part of the diet, medicinal value	Fires that raze large tracts of the forest, destroying habitats; Raze down trees that have taken generations to grow; Destruction of endemics in the forest.

	Debarking Harvesting of fibre for mat making	Harvesting bark to prepare medicine Harvesting of fibre for mat making	Drying up of plant species eventually losing the species altogether;
	Trees are cut down in Boni forest to be used as firewood or turned into charcoal.	Used for cooking and heating purposes.	**Deforestation;** **Global warming**
	Cattle herders	Cattle grazing	Loss of vegetation and local biodiversity
	Destruction of water springs	Overgrazing leading to trampling of water springs by cattle	Dry river beds, decline in regeneration of the forests dependent on the riverine environment including loss of biodiversity.
	Forest fires	Honey harvesting, slash & burn agriculture	Loss of large chunks of the forest, its biodiversity, loss of livelihoods for the Boni.
	Tree diseases		Poor forest health
	Poaching of forest produce	Socio economic gains	Reduced forest biodiversity

There were illegal activities in the forest (as indicated in Table 4.11) with the felling of trees using axes and mechanical saws being recorded between the years 2005 and 2010. Although the offences were not on a significant scale, they nonetheless represented a big potential threat to the forest especially where indigenous people were involved.

Table 4.11: Types of offences recorded by KFS, date of occurrence and the site. Source: Kenya Forest Service, Ijara Forest Zone (2010)

No	Type of offence	Area offence committed	Date	Tree species	Remarks
1	Illegal felling and transportation of *Terminalia spinosa* posts from Hulugho to Kolbio in Somalia Republic. The posts were impounded.	Hulugho area of Boni forest	August 2005	*Terminalia spinosa* (Hareli)	Several other cases of posts/poles being smuggled from Boni forest to Somalia have been reported
2	Illegal felling and ferrying of construction posts	Ijara division at Math-adon and Kuran area	August 2006	*Terminalia spinosa* (Hareli)	230 pieces of the posts recovered
3	Illegal timber sawing	Lamu-Ijara Sub Counties border	August 2007	*Afzelia quanzensis* (Bamba Kofi)	Use of power saws
4	Illegal timber sawing	Bothai in Bulto-harma area	September 2007	*Afzelia quanzensis* (Bamba Kofi)	80 pieces of timber impounded
5	Illegal felling of trees and timber sawing	Bothai area of Boni forest	January 2008 to September 2008	*Afzelia quanzensis* (Bamba Kofi)	Offence committed by a Canadian national of Somali origin who masqueraded as a farmer but illegally harvested trees during the indicated period. 3.7 tonnes of timber

					impounded from his allies.
6	Illegal timber sawing	Bandanguo area of Boni forest (Balisao)	April 2008	*Afzelia quanzensis* (Bamba Kofi)	Six trees cut down and sawn into timber
7	Illegal felling and transportation of *Terminalia spinosa* posts	Kotile area of Boni forest	August 2008	*Terminalia spinosa* (Hareli)	Posts and poles were being transported to Garsen town in Tana Delta District
8	Illegal timber sawing	Bothai-milimano area	August 2008	*Afzelia quanzensis* (Bamba Kofi)	Six people from Mpeketoni in Lamu District arrested and 1.2 tonnes of timber impounded
9	Illegal timber sawing	Bothai area	January 2010	*Afzelia quanzensis* (Bamba Kofi)	12 trees felled and sawn into timber

Note: Many cases of illegal timber sawing happened in the forest and were never reported or discovered

4.8.3 Forest fires

The researcher noted that fires were a major threat to the forest specifically in the southern part of the Sub County. The Government's programs of resettlement of communities in the forest led to the increase of slash and burn agricultural methods. The elders reported that farmers caused uncontrolled fires that spread to adjacent areas outside their swidden (slash and burn agriculture) resulting in wildfires. During the field work, such fires were evidenced by the observations of large open areas, scars on trees and were confirmed by the communities (during interviews and discussions) as a major threat to the forest. Threats from fire were found to impact heavily on the following species: *D. melanoxylon, A. quanzensis, N. hildebrandtii, S. africana, T. spinosa, T. prunioides* and *A. drepanolobium*.

4.8.4 Forest products sold locally

A number of questions in the questionnaire were dedicated to finding out whether the community purchased plant based items produced locally, and therefore made inference on forest exploitation. The sale of products in markets would also indicate the threat the forest faces due to meeting the need for such products. Table 4.12 presents the findings. The study noted that the local community does harvest honey and that this is mainly done by men. Both the Somali and the Boni communities had great knowledge on herbal medicines for both human beings and livestock. This was sold at household level but had not yet reached the level of being sold in the local market. Both men and women harvested medicinal products. All the goods and products obtained from the forest including timber, wild fruits, vegetables and others were not yet being sold in the local market.

Table 4.12: Plant products produced locally

Items	Sold	Local Market	Potential Vendor
Honey	No	None	Male
Herbal Medicine (Human &livestock)	Yes	None	Male and female
Building materials	Yes	None	Male and female
Furniture- chairs,	Yes	None	Male and female
Wild fruits/vegetables	Yes	None	Male and female
Wild fruits	Yes	None	Male and female
Swahili beds/baskets	Yes	None	Male

4.8.5 Analysis of threats on environmental sub components

Using Kruskal Wallis Test, the threats to the forest were analyzed and ranked. The results are presented in Table 4.13.

Table 4.13: Ranks environmental sub component

Environmental sub component	Threat on forest environment component	N	Mean Rank
Soil	Soil erosion	2	12.75
Grass layer	Over grazing	10	15.80
Herb layer	Over grazing, unsustainable extraction	23	21.85
Overall vegetation	Forest fires, drought, over grazing, deforestation, charcoal burning, timber sawing	4	23.50
	Total		**39**

The study established that there was a statistically significant difference (Kruskal-Wallis H (2) =7.040, *P=0.071*), between the threats on environmental subcomponents as indicated by farmers' perceptions. The mean ranks were 12.75, 15.80 and 21.85 for soil component, grass layer and herb layer respectively and the mean for the overall vegetation cover was 23.50.

There also exists a statistically significant difference between the threats in the forest (H (2) = 3.278, *P* = 0.051). Mean ranks of 7.50, 20.75, 19.89, 22.50 and 12.43 were recorded for forest fires, grazing/browsing, cultivation, settlements and pole cutting. However threats on the forest due to wood carving, honey harvesting and over grazing were lowly rated and communities do not see these as threats to the forest.

Table 4.14: Rank forest component

Forest component	**Threat on forest**	**N**	**Mean Rank**
Forest	Forest fires	2	7.50
Grassland in forest	Grazing/browsing	10	20.75
Forest	Cultivation	23	19.89
Forest	Settlements	20	22.50
Forest	Pole cutting	9	12.43
Forest	Charcoal burning	10	19.97
Forest	Wood curving	3	8.46
	Others	4	9.21
	Total	81	

There existed a statistically significant difference between the threats on Boni Forest (H (2) = 3.278, *P* = 0.051) with a mean rank of 7.50 for forest fires, 20.75 for grazing/browsing, 19.89 for cultivation, 22.50 for settlements and pole cutting at 12.43. However threats such as wood carving had the lowest mean rank of 8.46, honey harvesting, over grazing have a mean rank of 9.21 scores.

Table 4.15: Analysis of threats to Boni forest

	Threats to environmental sub components	**Threats to Boni forest**
Chi-Square	7.040	3.278
Df	3	3
Asymp. Sig.	.071	.051

4.8.6 Biodiversity and climate change

The study established that the forest is often used for grazing during prolonged drought period. 33.0% of the respondents use the forest during drought while 67% of the respondents do not. The study found out that the forest is used as a dry season grazing refuge by the larger Somali community residing as far as Garissa and its environs. The study tracked the drought years, the segment of forests used and the duration of usage as indicated in Table 4.16.

Table 4.16: Usage of forest environment during prolonged drought

Year of Drought	**Forest Used**	**Duration**
2009	Boni/Mangai	3 years
2007	Boni/Bodhai	2 years
2006	Boni/Bodhai	1 year
1992	Boni/Hulugho	1 year
1988	Boni/Mangai	1 Year

31.6 % of the respondents informed the study that there were other forest resources that they used to cope with prolonged drought. Examples of these included Mariga which is a poisonous plant but when cooked it can be eaten after two days and Kama which are fruits eaten by men. Others included Mkalabaka (*Bredelia cathatica*), and Dabe (*Vepris glomerata*).

4.8.7 Community perceptions on threats to the forest resources

Significant threats to the forests were identified including; deforestation which involves clearance of vegetation, forest fragmentation and settlements (increased numbers of structures/houses). Conversions of forestland into agricultural landscapes were cited as a significant environmental threat. In Mararani, communities indicated wildlife as a threat to the forest and poor enforcement of laws. In all the other study areas, responses indicated that forests were degraded due to local factors among the community. Such factors included slash and burn, settlement and illegal logging which were ascribed largely to the communities. This was an indication that communities knew the source of problems to their forest resources which was important in developing forest rehabilitation programmes.

4.8.8 Threats ranking

Using pair wise ranking, the threats were ranked giving the most serious threat first.
These were:

1. Deforestation by shifting cultivation
2. Settlements in the forest
3. Harvesting timber/logging
4. Grazing
5. Bush/forest fires
6. Illegal removal of building poles

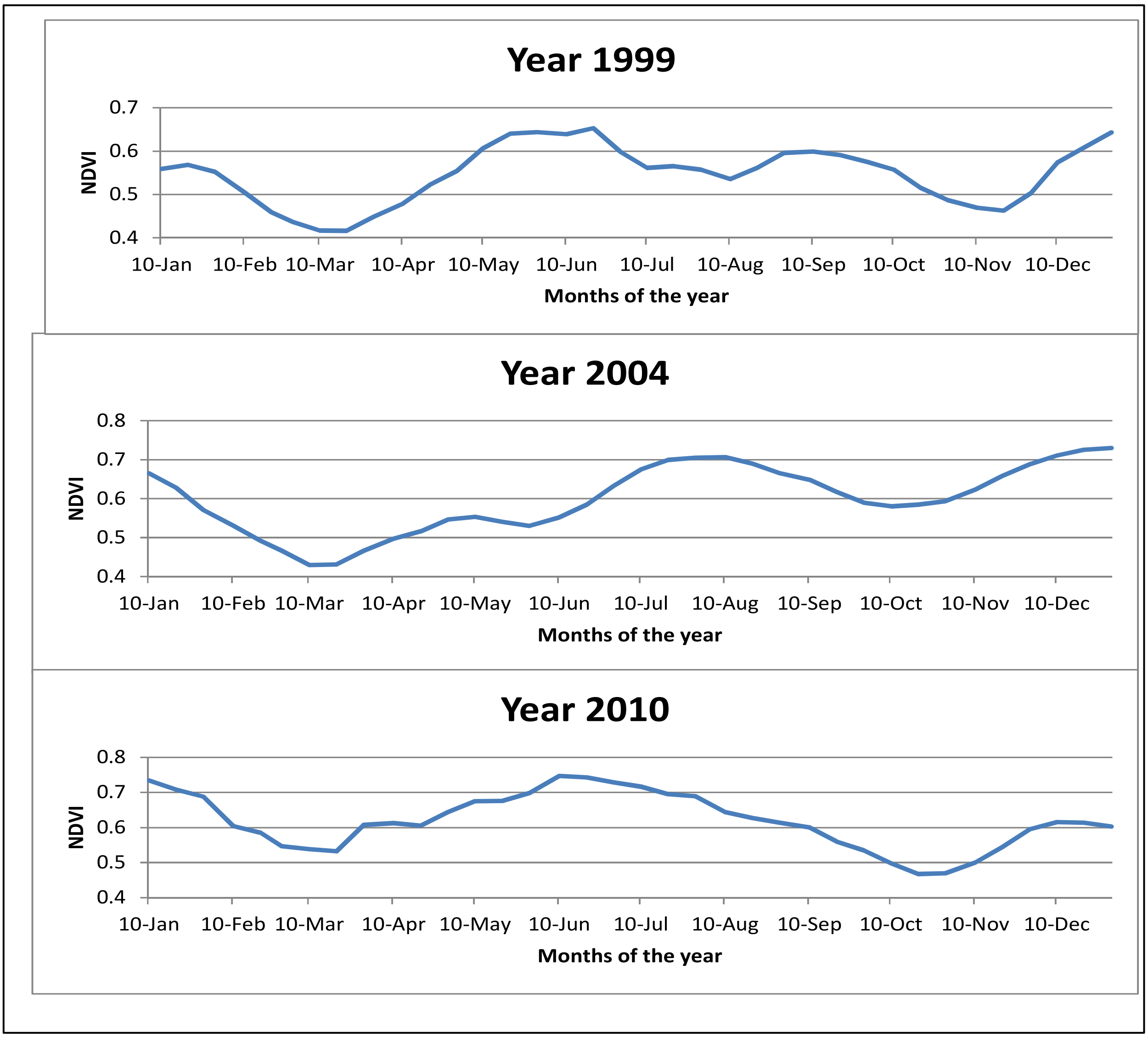
The major threat to the forest was the level of deforestation whose estimates still needed to be calculated to depict the number of hectares being decimated annually. The main causes of deforestation were:

- Increased logging activities;
- Expansion of agricultural activities due to need to ensure food security, a move being pushed by the Ministry of Agriculture, and
- Establishment of settlements in the forest.

In the case of logging activities, as noted earlier, there was over-exploitation of a few selected high grade timber species such as *Terminalia spinosa* and *Afzelia quasensis*. For these species, they proved to be very difficult to regenerate, making their future very uncertain and threatened. One of the major markets identified during the study was from a Canadian of Somali origin. Most valuable indigenous timber tree species are selectively harvested, aimed at removing the best mature trees leaving unsalable and defective trees. Some of the indigenous tree species are now in danger of genetic impoverishment while others are threatened with extinction. The study noted the quick response from KFS to apprehend culprits and save the threatened species.

4.8.9 Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) data was used to assess change in forest vegetation for the period 1999 – 2011 (Appendix 4).



The figure indicated that the vegetation health decreased from a high season of December

Figure 4.5: The trend of vegetation health in the seasons of the year

attaining low values in mid-March. This trend was similar in all the years between 1999 and 2011. The best vegetation health was attained in the period between mid June and mid September followed by a small decline which peaks again towards December.

4.9 Indigenous knowledge systems Related to Conservation of Biodiversity and Utilization of Plant Species

This section presents findings under objective four whose primary quest was to answer the question- what indigenous knowledge systems exists for conservation of biological diversity among the Boni and the Somali. During administration of the questionnaire, it was noted that among the Boni, women had been empowered and freely shared information that they had. However, among the Somali, women continue to be shielded from outsiders making it virtually impossible to interact with them. At a certain location, the team was strongly instructed not to administer the questionnaire to women. The study deduced a lot of influence from religion on this matter rather than purely from the traditional African culture *per se*.

4.10 Characteristics of the Sampled Population

4.10.1 Sample size interviewed

In the study, a sample size of 257 was targeted to be interviewed. The sample comprised communities from the following sub locations all living adjacent to or inside the Forest, further illustrated below: Hulugho, Sangailu, Masalani, Ijara, Kotile, Jalish, Handaro, Milimano, Korissa, Mangai, Hara, Dololo, Bodhai, and Abasuba. However, the actual number interviewed was 100.

4.10.2 Socio-economic information

Access to infrastructure and services

The study sought to establish access to infrastructure and services. An item was therefore included in the questionnaire which sought information on the distance from homesteads to the nearest shopping centre, primary School, government clinic, developed water source and government agriculture and livestock offices. Table 4.17captures the findings. According to Table 4.17, majority of the interviewees (67.2%) reside more than 2km away from the nearest shopping centre, 65.6% were over 1km away from primary schools, 72.7% were over 1km away from a government clinic. Generally the study found out that most of the respondents had quite limited access to infrastructure and services.

Table 4.17: Access to infrastructure and services

Infrastructure and Services	**Distance to infrastructure and services in meters**			
	0-500	**501-1000**	**1001-2000**	**Above 2000**
Distance to shopping centre	10 (14.9%)	9 (13.4%)	3 (4.5%)	45 (67.2%)
Primary school	13 (19.4%)	10 (14.9%)	22 (32.8%)	22 (32.8%)
Government clinic	6 (9.1%)	12 (18.2%)	19 (28.8%)	29 (43.9%)
Developed water source	11 (18.6%)	6 (10.2%)	31 (52.1%)	11 (18.6%)
Livestock and Agriculture offices	1 (2.2%)	1 (2.2%)	1 (2.2%)	43 (93.5%)
Total	**100 Respondents**			

Household information

In a bid to establish the household information, an item was included in the questionnaire which sought information on age, gender and the number of people living in each household. Table 4.18 presents the findings. The results showed that the average number of males per household was 3 while the average number of females per household was 2. In terms of age groupings, the study found out that there were on average 2 males and similarly 2 females per household between the ages of 18 and 50. The study further revealed that there was on average one male and one female respectively that were above 51 years per household.

Table 4.18: Household information

Ages	**Male average per household**	**Female average per household**	**Grand Total**
Less than 18 years	3	2	5
18-50 Years	2	2	4
Above 51 Years	1	1	2
Total	**6**	**5**	**11**

Age of respondents

The age of respondents was one of the attributes that the study examined to establish the impact of age on conservation and management of the forest with the underlying assumption that indigenous knowledge holders would lean towards conservation and that older people would be more prone to use their indigenous knowledge to ensure conservation of natural resources while the younger generation would squander the opportunity to learn from the old. The study examined whether age was a factor in forest decimation.

Table 4.19: Age of the respondents

Age	**Frequency**	**Percentage**
18-30 Years	30	30.0
31-40 Years	13	13.0
41-50 Years	20	20.0
51-60 Years	24	24.0
Above 60	9	9.0
Declined to respond		4.0
Total	**100**	**100**

The study found that 30.0 % of the respondents were between the ages of 18 and 30, reflecting that this was probably the largest age bracket in this community and the most active. Six (13.0%) of the respondents were between ages 31 and 40. 20.0% of the respondents were between 41-50. Respondents aged between 41 and 60 represented 24.0% of the total respondents. On the other hand, 9.0% of the respondents were in the 60s and above category. Lastly, 4.0% of the respondents declined to respond. The apparent diversity of the maturity of the respondents had several implications on the study's findings.

Level of education

In a bid to establish the level of education, an item was included in the questionnaire which sought information on the level of education of the respondents. Figure 4.6 presents the findings. As indicated in the figure, majority of the respondents (72.9%) had no education at all, 22.9% had primary school level of education and only 1.4% indicated they had attained secondary school education. 2.9% declined to state their level of education. Among both the Somali and the Boni, (more so the Boni), the literacy level was extremely low, even just by observing that there were no institutions in the area. Among the Boni, the study noted one lower primary school deep in the Forest with only one teacher. This tended to cast a slur on the ability to negotiate for sale of resources even under willing buyer willing seller concept and therefore posed a fundamental threat to the forest.

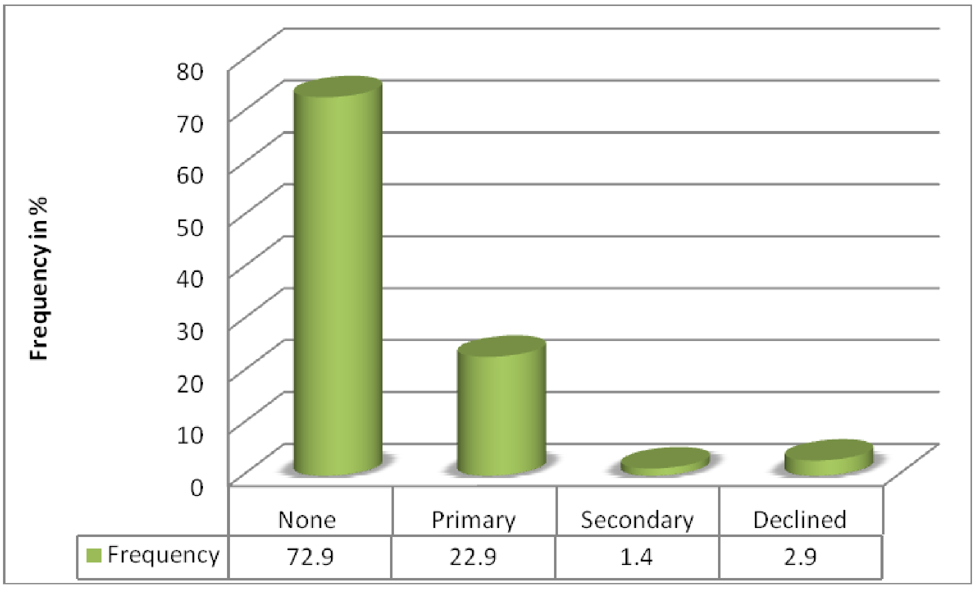


Figure 4.6: Level of education

Source of income

The study sought to know the primary source of income of the respondents. Therefore an item was included in the questionnaire which sought information on the same. The findings showed thatlivestock keeping was largely the main source of income as indicated by 45.0% (Table 4.20) followed by crop production at 25.0%, closely followed by 14.0% who cited both livestock keeping and crop cultivation as their source of income. Formal employment, artisan work and poultry/livestock were cited by only 1.4% respectively as their source of income. In terms of total income per month of the people living in Boni Forest area, the study revealed that the average income was 38,818.50 Kenya shillings per annum, with a minimum income at 900 and the maximum income of 150,000 Kenya shillings.

Table 4.20: Sources of income

Sources of income	Frequency	Percentage
Livestock keeping	45	45.0
Crop cultivation	25	25.0
Livestock and crop cultivation	14	14.0
Formal employment	1	1.4
Artisan worker	1	1.4
Poultry and livestock keeping	1	1.4
Formal employment and livestock keeping	2	2.9
None	11	15.7
Total	**100**	**100**

Distance from the resources

Table 4.21: Distance from the vital resources

Distance (m)	Vicinity to Forest		Vicinity to Water		Vicinity to Grazing Land	
500	19	19.0%	26	26.0%	28	28.0%
600-1000	27	27.0%	24	24.0%	23	23.0%
1500-2000	10	10.0%	11	11.0%	11	11.0%
Above 2000	27	27.0%	23	24.0%	21	21.0%
Declined to respond	17	17.0%	16	16.0%	17	17.0%
Total	**100**	**100**	**100**	**100**	**100**	**100**

37.0% resided 600 metres to 2km away from the forest while 61.0% resided close to water bodies including the swamps and the lake. 72.0% of the respondents had close proximity to grazing land. This had critical implications on how the society interacted with and appreciated both goods and services from the forest.

Other livelihood strategies

The study also delved further to categorize livelihood strategies, their level of importance and reason for practice with a view to capturing the underlying causes of forest decimation among the various community segments. A comparison of evolving livelihood strategies and adaptation mechanisms was also undertaken (Tables 4.22, 4.23 and) and the study found that emerging livelihood strategies were mainly introduced by government agencies such as the Ministry of Agriculture, Arid Lands Management Project among others with a view to diversifying coping strategies in the already harsh environment. The study noted the potential to exert pressure on forest resources in order to create wealth was on the rise. Livestock keeping was seen to cause more harm to the forest especially during the drought years when the herders use the forest as a dry season grazing refuge. Honey harvesting as a livelihood was also on the rise and had great potential to decimate the forest due to fires. The youth were engaged in making carts which were used to transport various products to and from the newly introduced farms. The study also found that this will be destructive in the long term.

Table 4.22: Current Livelihood strategies and in the past 20 yrs, level of importance, extent and reason for practice

Strategy	**20yrs ago**	**10 yrs ago**	**Now**	**Future**	**Scale**		**Remarks**
					Food	**Sale**	
Herding & Livestock trade	3	2	2	1	1	3	There is decreasing forage and increased drought occurrencies. Lack of market means very few people engage in the trade. Tsetse fly menace threatens the survival of livestock Households are turning to farming as a secure source of livelihood in the process destroying the forest. Potential to destroy forest quite high, effect & impact of drought quite severe. As livestock population diminishes and people embrace other livelihood strategies, there will be no herding labour. High potential for youth to turn to the forest for survival. Livestock trade is very minimal, youth turning to charcoal burning, very destructive to the environment.
Sheep and goat rearing	1	1	3	3	3	3	There is decreasing forage and increased drought occurrences.
Milk selling	2	1	3	3	1	1	Most house holds do not have milk producing cows. They get milk from goats and sheep. Mainly done by women to get income to buy food. Serves as an alternative income therefore keeps them off forest destruction to a measure.
Donkey cart transport business Transport business	0	0	2	3	1	1	Increased need for transport as people take up new livelihood strategies. Donkey carts are the only means of transport during migration with livestock and are also used for transporting forest products. There will also be increased demand to transport farm produce to the homes.

							Illegal pole harvesting is undertaken to make these carts thus further decimating the forest.
Hotel kiosk	0	0	2	3	1	1	Evidence of changing lifestyles. Income from selling forest products used to finance these enterprises. Customers main source of income is from forest products
Small shop	0	0	3	3	1	1	Potential to cause cumulative impacts to ecosystems as people search for NTFP to create wealth to be able to purchase goods from shop. Residents go to Ijara 40 Km away to buy food and other items which are not available in the local shop
Poultry	0	0	2	3	1	3	Becoming popular and is a livelihood strategy that relieves pressure from the forest and allows regeneration
Honey selling	0	0	3	3	1	2	Harvesting honey does cause forest fires. Becoming popular as a fall back position. If undertaken sustainably occasions no harm to the forest
Crop Farming	1	1	2	3	3	3	Low milk production has made more people to take up farming. Forest decimation to expand farm land is ongoing There is a big potential for forest destruction in pursuit of high value crops
Casual jobs	0	1	2	3	3	3	Changing lifestyle is increasing the need for menial jobs such as charcoal burning.

Code:0=does not exist, 1=a bit important& done by a few people, 2=important done by about 50 % of the population, 3=very important done by nearly everyone

Table 4.23: Segmentation of the community into livelihood activities

Livelihood Activities **Community segmentation (%)**	**Men**	**Women**	**Youth**
Farming	60	30	10
Cattle rearing	30	10	60
Sheep and goats rearing	20	20	60
Honey collecting	50	0	50
Milk marketing	0	90	10
Handicraft/weaving	0	60	40
Sale of forest products	60	0	40
Donkey cart transport	95	0	5
Employment outside farms	90	0	10
Traditional herbalists	80	20	0

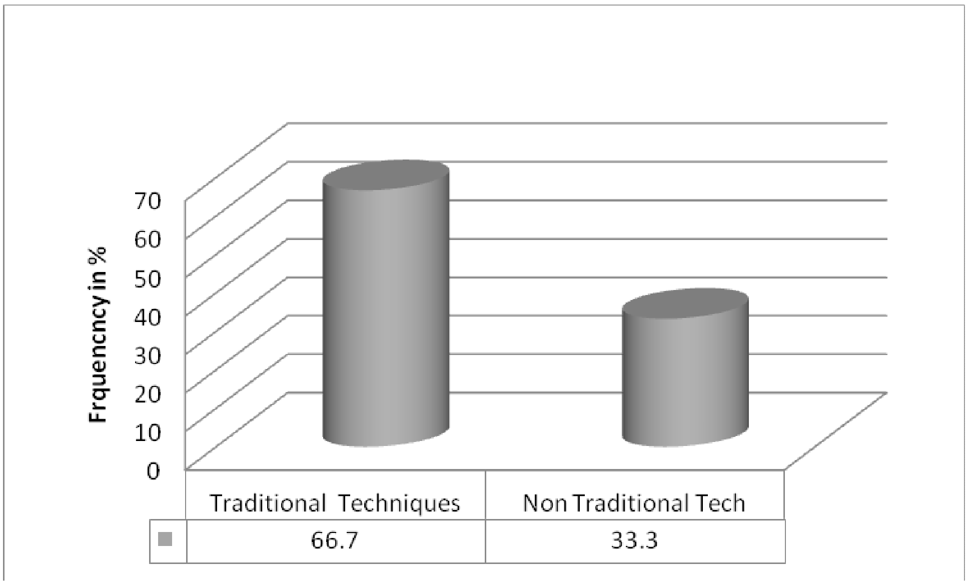
4.10.3 Boni community's traditional knowledge of naming plant species –

Boni community's traditional herbalists have achieved a lot in naming of plants like Acacias, Grewias, Commiphora and Euphobia. They segment a plant by the taste of its fruits or by the disease it cures. Many of the plant species derived their names from peculiar taste, diseases they treated and various shapes among other symbolic naming patterns. For instance, *Manilkara mochisia* (wardhe) was distinguished because of its many close-knit branches and the edible ripe fruit. *Encephalartos hilderbrandtii* (thielle, tielle) was identified as a large container for carrying commodities. The plant had large fruits (one filled a basket made from hollow wood or palm leaves). The name given to *Grewia* was (Dik Deka) implying just one drop of the concoction from this plant was sufficient to cure an ailment. All Euphorbia in Boni were refered to as Baraidi which meant Pray God. All Acacia were termed as Bura, meaning many flowers and fruits. Aloes were all known as Harges meaning a cure for malaria and small pox. *Commiphoras* were called Dakida Hagersu meaning open space, in that one could hide inside the bushes. *Ormocarpum* was referred to as Butiye because the bark resembled a puff udder. A lot of the naming systems and patterns were fixtures on the shape of the plant species, fruit taste and the diseases they cured.

4.10.4 Indigenous knowledge systems for biodiversity conservation: sustainable harvesting techniques of plants

An item was included in the questionnaire which sought information on the traditional techniques used to promote sustainable harvesting techniques of useful plants and Figure 4.7 presents the findings.

Figure 4.7: Techniques Used



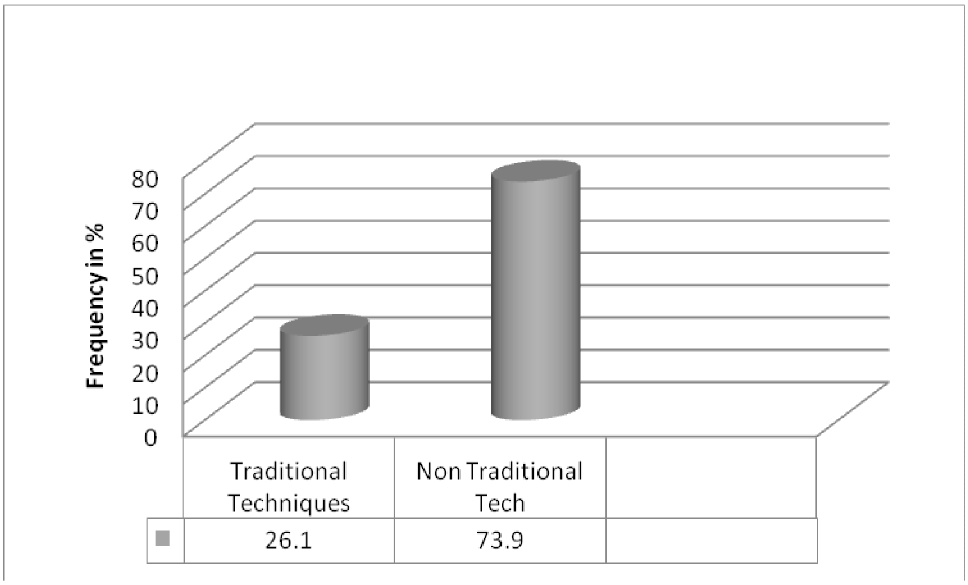
The study found that 66.7% of those interviewed used traditional techniques such as harvesting of products only when there is a need like a wedding, house construction or any other communal function. The Boni have banned the marketing of forest produce thus further reducing the potential to exploit the forest unsustainably. Other methods include protecting trees while growing, harvesting only the portion required for food while retaining the whole tree. The study also noted that the Boni draw their harvest from plants that are mature. It was also noted that they only harvested fallen logs for fuel wood, maintaining appropriate harvest levels.

4.10.5 Indigenous knowledge systems used for conservation

Regeneration and propagation of useful plant species

The study found out that only 26.1% of the respondents used traditional techniques to promote regeneration and propagation of useful plant species like those species used in fencing homesteads as shown in Figure 4.8 below.

Figure 4.8: Techniques Used to Promote Regeneration and Propagation



Examples of these species include Hareri, Casuarina among other species. 32% of the respondents use IKS for managing and conserving the forest; 8% use IKS to enhance forest productivity by protecting the forest using traditional regulations (Figure 4.8). The Boni communities have indigenous knowledge systems on seed propagation which ensures continuity of certain plant species. They know which species have regenerational problems and how to propagate them having acquired such profound knowledge from years of trial and error. Local people are aware of the extent of variation as well as the traits displayed by genetically superior individual trees or intraspecific taxa. They also have indigenous knowledge systems on plant physiology, understanding of their reproductive biology, knowledge on species that thrive in the dry season and those that provide dry season pasture and food.

The communities have knowledge on the role of other organisms in the dispersal of seeds of specific trees. For example birds disperse leguminous plants which bear seeds in pods and these are largely members of the family Mimosaceae. They also know the value that trees serve to other non-human organisms as food. For example, specific trees that flower at specific seasons are a source of nectar for bees and it is possible to determine the trees that have provided honey at specific times of the year. The study noted deliberate preservation of corridors of mature forests between plots as some kind of biological reserve to provide habitat and food for animals which are of importance to the community.

4.10.6 Indigenous knowledge systems for management and conservation of the forests

Figure 4.9: Illustrates that in all the study locations, the communities value IKS for management and conservation of the forests.

Most of the respondents (> 67% in all the study locations) believe that IKS can help manage and conserve the forests which have been degraded. The figure also shows that communities believe that IKS can be used to enhance the productivity of their forests.

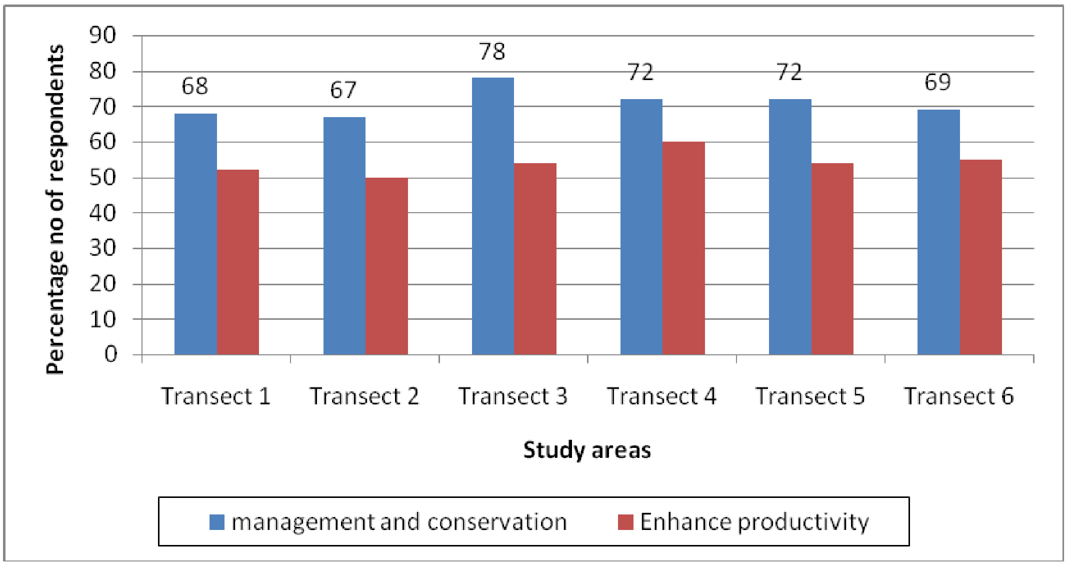


Figure 4.9: Community response on use of IKS in management, conservation and enhancing productivity

Transect 1 representing Mararani was located on the southern side of Ijara Sub County and comprised largely of coastal variety of species and trees had a closed canopy, Management and conservation of the forest was at a value of 68% while enhancing productivity was at 50%.

Transect 2 representing Managai was located on the southern side of Ijara Sub County outside the Boni forest on the northern side. The coastal effect on vegetation slightly reduces giving rise to Acacia commiphora woodland. The transect was frequently crossed by Boni community to reach water sources especially during drought leaving traceable trails. The value of management and conservation of the forest is at 67% while enhancing productivity was at 49% which are relatively low compared to the other transects. This was attributed to the frequent and easy accessibility by the Boni to the area in search of water among other goods and services from the ecosystem.

Transect 3 representing Bodhai was located in Bodhai area which was on the south western side of Ijara next to the riverine forest of the Tana River. This comprised of closed canopy forests due to the riverine effects and the adjacent coastal forests. Management and conservation of the forest was at 78% while enhancing productivity was at 58% and was the highest compared to the other transects. This was attributed to proximity to the Tana River and focus on agricultural practices rather than forest exploitation.

Transect 4 representing Sankuri was located in Lungi block of the Boni forest. The transect started from the hill top with thick forest. The forest had a closed canopy. Management and conservation of the forest was at 72% while enhancing productivity was at 60%. This was attributable to the impenetrability of the closed and thick forest.

Transect 5 representing Hulugho was located in the northern side of Ijara Sub County where it was drier in Acacia commiphora woodland. The area had high livestock and wildlife density. Management and conservation of the forest was at 72% while enhancing productivity was at 55% attributable to functional indigenous systems that regulated use of resources.

Transect 6 representing Sangailu was located in the northern side of Ijara where it was generally dry. Land was communally owned and the forests were not gazetted. Management and conservation of the forest was at 69% while enhancing productivity was at 56% attributable to poor enforcement of both indigenous conservation systems and procedures and the legal structures by KFS and KWS since the forests on this end were not gazetted.

4.10.7 Sacred groves

Investigations into the traditional resource use norms and associated cultural institutions prevailing among the Boni demonstrated that a large number of elements of local biodiversity, regardless of their use value, were protected by the local cultural practices. Sacred groves and forest zonation for use was largely undertaken by the elders. The number of sacred groves was more in the forest of southern Ijara where 95% of the sacred groves were recorded. Highly valued timber species like *A. quanzensis, T. spinosa* and *B. huilensis* were still abundant in these areas and this could be attributed to the presence of sacred groves. These forest fragments were of varying sizes, communally protected and were used for religious purposes mainly by the Boni. Hunting and logging were strictly prohibited within these patches. Other forms of forest usages like honey collection and deadwood collection were sometimes allowed on a sustainable basis under supervision by one of the elders appointed to man the sacred groves. Members of the community took turns to protect the sacred groves using a highly complex rota designed by the elders. Part of the success in protecting these forest patches derived from the deeply convoluted myths passed from one generation to another on how destruction of life followed those who destroyed flora and fauna found in the grove. The Somali community used *Opuntia vulgaris* to mark shrines. Most places in the forest had some sacred places used as shrines by the community. Sacred groves that were highly valued by both communities further enhanced conservation of the forest where these groves and shrines were found. Harvesting of forest products in such areas was prohibited and whenever restrictions were lifted, the harvesting was strictly supervised by elders. Species that held high medicinal value tended to be protected from exploitation by the community in such groves thus ensuring that they did not lack the medicine since they highly rely on herbal medicine. Species that are protected for their medicinal value include: *P. stahlmanii* (used to drive out demons, *C. anisata,* (used to treat snake bites and stomach pain), *H. inopleum*, (used for dental treatment), *S.s henningsii*, (used to treat stomach disorders and bilharzia), *T. trichocarpa*, (used to treat common colds, headache and malaria), *H. opposita* (used to treat common cold and fresh wounds).

4.10.8 Protected and conserved species

The study established that a number of species were protected by traditional regulations. Though some of the communities had preserved species, the non harmonious ethnic composition of the community resulted to either of the inhabitant communities having an exploitative activity for each species. Such species would therefore be classified as community conserved species. Figure 4.10 illustrates that *L. schweinfurthii* had the highest preference for protection at 81% of the respondents followed by *A. digitata* at 79% and *A. obesum* at 78%. Various reasons were given for the protection of these species. For example *L. schweinfurthii* was protected due to its role in the forest web and the variety of uses that the species had and many respondents stated that they would not exploit any of its parts. However, it was found that among some community members, the tree had edible fruits that supplemented the household diet. The root was also highly valued for wool production while the bark was used to treat stomach ailments. As for *A. obesum* (the desert rose which is highly poisonous), it was widely used medicinally.

The study however found out that due to an increase in population specifically among the Boni community and the frequency of the dry seasons, some plants were over harvested and faced complete destruction in the near future. Examples of such plants include:

The local community had 10 trained community guards in each village who guarded the reserve and were quite knowledgable about plant species names, values and uses. The two groups (Somali and the Boni) shared the same shrines and other places of worship among other cultural ceremonies. From observations, the study noted stacks of the following plant species: *N. hilderbrandtii*, *C. nilotica* and *N. erlangeri* in almost all homesteads. The Boni utilized these species for fuel wood and were very strict that the fire wood collection revolved around only these 3 species. They broke smaller branches of herbs and shrubs such as *C. pseudocan* and used them as a way of marking a trail. Some of these trails marked where wild bee hives were found. The same trails were used by the forest guards for patrolling the forest. Figure 4.10 showsspecies with high preference for protection

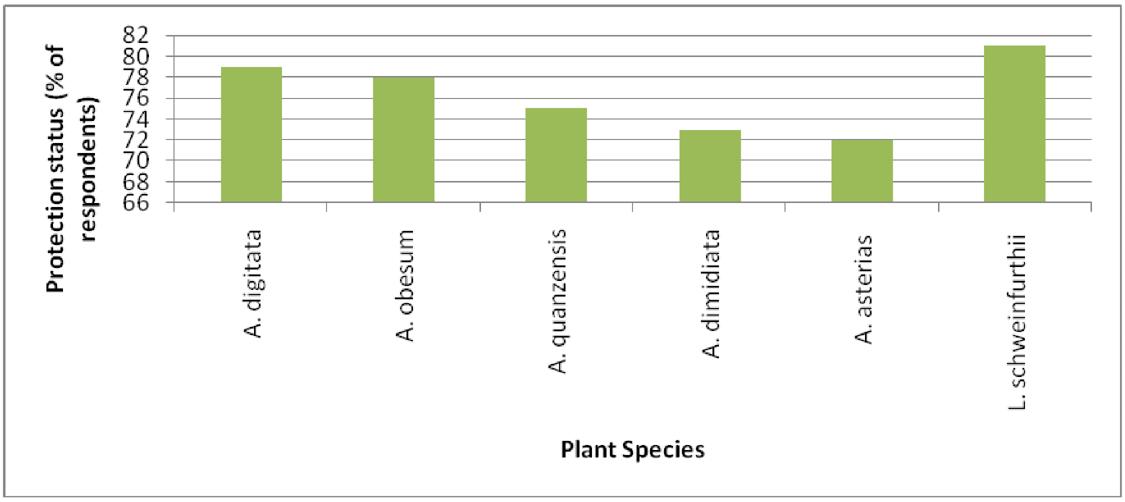


Figure 4.10: Protection status of plant species

4.10.9 Species and areas that were protected

From this study, 70.0% of the respondents revealed that sacred plant species were protected from overuse by heads of families and village elders who outlawed cutting of certain species or grazing in certain areas. Examples of some of the protected species included Horop, Roga and Tuwer which were all used for prayers. Other plants included Icheni and Machach. 76.0% of those interviewed were aware that there were important areas that were protected from over utilization and gave examples such as sources of rivers and groves with plants used to feed the community during drought years. 81.0% of the respondents informed this study that certain areas were set aside to be used for grazing especially during drought periods while15.0% indicated that certain areas were considered sacred and not open to grazing or for other uses. An example given by a number of those interviewed was the Rungi area in the forest used commonly for prayers and paying respect to the ancestors. 26.0% of those interviewed said that there were no areas or resources whose access was restricted to certain groups.

In terms of protection of resources, the traditional approaches used to protect useful plants, forests and water sources included barring both cultivation and burning of the forest vegetation. Penalties were not definite measures but rather a series of prescribed personal disasters that would over time happen to offenders.These myths / threats seem quite effective as deterrents to forest destruction. 98.9% of the respondents informed the study that there were no private or communal seed banks for valued species in the area.

4.10.10 Plant species utilized among the Somali and the Boni for medicinal purposes

It is common to find, in Africa, that almost all communities possess knowledge of plants (and in some cases animals) with medicinally active compounds which enable them to cure diseases prevalent in their specific locality. For the Somali and Boni communities, the species commonly used, diseases or conditions they treat, name of the area commonly found and whether obtained from the forest or rangeland are indicated in Table 4.24. The most commonly used plant species was *Teclea trichocarpa* at 24.3% used to treat flu and malaria, followed by *Maytenus undata* at 21.4% used for treating cold/flu and stomach disorders. The study further revealed that *Haslundia opposita* and *Terminalia spinosa* both at 7.1% are used for treating cold and dental problems respectively, the rest 34.4% were utilized as shown in Table 4.24

Table 4.24: Species commonly used by Boni and Somali communities from Boni Forest

Species	**Scientific name**	**Diseases/Conditions it treats**	**Name of the Area obtained**	**Got from Forest or Rangeland**
Mwangajini (Boni)	*Polyalthia stahlmanii*	Drive out demons	Mangai	Forest
Nyongei (Boni)	*Clausena anisata*	Snake bite, stomach	Mangai	Forest
Arero (Boni)	*Haplocoelum inopleum*	Dental treatment	Mangai	Forest
Mtubako	*Strychnos*	Stomach, bilharzias	Bodhai	Forest

(Boni)	*henningsii*			
Kakaley (Boni)	*T. trichocarpa*	Cold, malaria, headache	Mlimani	Forest
Jalmaley (Boni)	*H. opposite*	Cold, fresh wound	Bodhai	Forest
Mek (Somali)	*O. sennoides*	Cold, newborn baby	Bodhai	Forest
Rul (Somali)	*P. chrysoclada*	Cold, mental, snake bite	Bodhai	Forest
Samarey (Sawecha) Somali	*D. melanoxylon*	Stomach, male impotence	Bodhai	Forest
Aworzi (Abozi)	*B. hutchinsii*	Tsetse bite, stops bleeding, tick	Bodhai	Forest
Mbarambarey (mbarara) (Boni)	*O. somalensis*	Chest, back, stomach	Bodhai	Forest
Akikahe	*S. zansibariensis*	Malaria, tooth pain	Milimani	Forest
Mbalambata	*M. undata*	Cold, flu, stomach	Milimani	Forest
Mitilili (Muarobaini) (Somali)	*A. indica*	Malaria, fruits, pesticide	Milimani	Forest
Casuarina	*C.equisetifolia*	Coughs, flu, headache	Milimani	Forest
Papura	*A. ravumae*	Backache, flu	Milimani	Forest
Arer (hareri) (Somali)	*T. spinosa*	Dental problems	Bodhai	Forest
Hakari (haggr) (Somali)	*C. baluensis*	Chest pain, oil	Bodhai	Forest
Sena	*S. siamea*	Kidney	Bodhai	Forest

4.10.11 Plant species used as timber/wood for building

The study sought to find out timber/wood and other types of forest products the communities use for building. 87.0% of the respondents said they used timber/wood while 13.0% indicated that they did not use any of these products. Table 4.25 shows the species commonly used for building and thatching, name of the area obtained and whether obtained from forest or rangeland.

Table 4.25: Species commonly used for building and thatching

Species local name	Scientific name	Name of the area Obtained	Forest or Rangeland
Hareli	*T. spinosa*	Mangai, Bothai	Forest
Shamada	*D. melanoxylon*	Mangai	Forest
Mtabaini	*T. boivinii*	Mangai	Forest
Agoa	*H.crinita*	Mangai	Forest
Mbudhi	*N. kaessnerii*	Mangai	Forest
Aworzi	*B. huichinsii*	Milimani	Bothai
Mwangati	*T. prunioides*	Milimani	Forest
Salisandi	*P. golungensis*	Milimani	Forest
Chendewira	*C. nilotica*	Milimani	Forest
Rashidi	*T. orientalis*	Milimani	Forest
Shipapu	*H. abyssinica*	Milimani	Forest
Kurat	*D. cornii*	Boni	Forest
Msumalini	*L. bussei*	Bothai	Forest
Not available	*T. danis,*	Bothai	Forest
Not available	*U. acuminate*	Bothai	Forest
Not available	*G. tenax*	Bothai	Forest
Not available	*P. villosa*	Bothai	Forest
Not available	*C. aculeatum.*	Bothai	Forest

According to the findings, 25.7% of the respondents used *T. spinosa* for building, 15.7% used *B. huichinsii* and 12.9% used *T. prunioides*. Other species like *C. nilotica*, *H.abyssinica* and *D. cornii* were used by 5.7% of the respondents each while 25.7% used other species as shown in the table. From observations, there was quite a bit of construction involving the use of the following species: *T. danis, U. acuminate, G. tenax, P. villosa* and *C. aculeatum*. The study observed that among the Boni community cutting trees and building houses was done by both men and women. They selected plant species that regenerated and matured quickly therefore allowing time for restoring the forest cover.

Although some species were identified as preferred timber species (Fig. 4.11), the timber business was labelled as illegal by respondents and thus only done secretly behind the government knowl\edge and was therefore not identified as a permanent source of livelihood. Communities indicated that about 10 species account for the total timber value of the forests with *T. spinosa* being the most widely used. This species was valued for its durable timber but had a limited ecological range which made its exploitation probably non-sustainable in the area. *P. africana, D. melanoxylon and A. quanzensis* were also cited as significant timber species. *R. mucronata* a mangrove species that was found on the intertidal zone of the coastal forests of southern Ijara was also listed as a significant source of timber (2% of the responses), illustrating that forest products from the coastal region were accessed by the local communities even in the far northern parts of the Sub County. In the absence of an external market, most respondents stated that the amount of timber exploited for local consumption would be sustainable as removals from the forest would in essence remain low. However, if the timber was collected and sold outside the Ijara area, then the forests were likely to be degraded with the continued high removals.

Trees were noted as an important raw material in the building and construction industry in this largely rural set up. In making these non permanent structures, termite resistance was noted as a major aspect influencing preference. However, when the preferred species were no longer available, other species took up this role. Such species included *A. asterias, N. kaessneri, E. suaveolens, O somalensis, D. cinerea, N erlangeri, A dimidiata, E. capensis, and C. zimmermannii*.

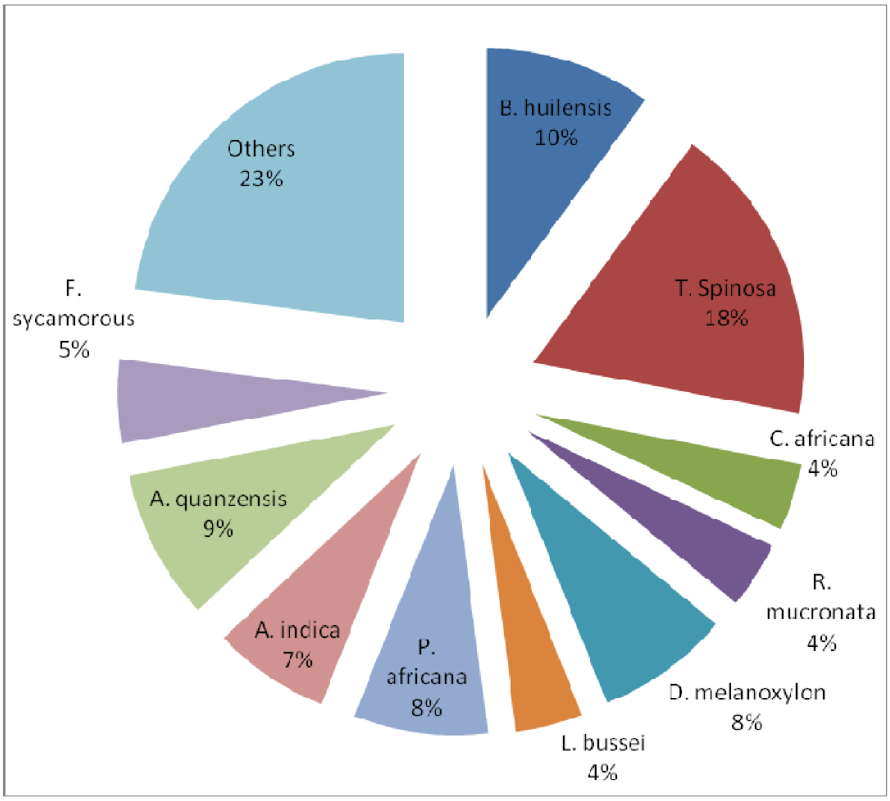


Figure 4.11: The percentage use of selected tree species for timber purposes

4.10.12 Use of trees for fuelwood and charcoal production

The community indicated that they use fuelwood from the forest for cooking with 98.0% of the respondents informing the study that fuelwood was the most preferred source of energy. A number of people said that they used charcoal which they made occasionally. The respondents informed this study that the species commonly used for firewood and charcoal included Aworzi (*B. huichinsii*) and Samach (*D. melanoxylon*). Others were Harori *(G. plagiophylla)*, Tokohoji warade (*H. inopleum)* Morhoqa *(T. indica)* and *M. mochisia*. Most plant species were noted as good sources of firewood, except some species such as *Croton sp* that were avoided for some reasons such as a strong pungent smell. The study noted that *C. pseudopulchellus*, a member of the Croton family, was one of the most abundant species as indicated in the vegetation surveys and this could be associated to its being seldom utilized. *C. nilotica*, a tree of the coffee family whose relative abundance was high, was mentioned as a good firewood species at all the sites due to its non-smoky wood, ease of availability and optimal heating characteristics. Despite the generality of fire wood usage there were preferred species for this use. These included *D. melanoxylon, C. schumannii,* and *C. suahiliensis*. The community indicated a decline in the firewood availability (40% of the respondents) and cited species like *B. huilensis*, and *D. melanoxylon* as some of the trees whose availability had considerably declined. Observation surveys confirmed the availability of fuel wood in the various compounds which was kept in large stacks in virtually all the homesteads, attesting to the fact that firewood was readily available in the forest albeit an increase in the distance to cover to collect it compared to years past.

For charcoal production the species preferred were mostly from the *Acacia* family such as *A. seyal, A.bussei* and *A. nilotica*. Due to the uneven distribution of these species as indicated by the species dominance results in section 4.3, the two communities indicated different preferences for these species. The Boni had higher preference for *A. seyal* while the Somali preferred *A. nilotica.* These species were found within easy reach of the homesteads, mainly in the grasslands. The reason for the preferences lay mainly in the fact that the Boni being hunter gatherers preferred the *A. seyal* because they use the stems to make shafts for their spears, the wood being used for a variety of things, the gum produced by the tree is edible, the bark high in tannin and the leaves are also used for fuel. The Boni also rely on it because of the tannin in the bark, which is used to treat dysentery and a number of other illnesses. The gum produced is used to treat chronic diarrhea, colds, and even hemorrhaging. The wood of this tree is used to reduce fever, as well as treat pain associated with arthritis.

4.10.13 Usage of natural plants as food/fruits

The study further sought to establish the usage of naturally occurring plants as food/fruits, specific part of the plants consumed, area obtained and the season in which they were used (Table 4.27). Majority of the respondents (30.0%) used *B. cathatica* as food particularly its fruits and stem, followed by *C. triflora* (12.9%) whose fruits were consumed, 11.4% ate *G. villosa*, 8.6% *Z. chalybeum* and 7.1% consumed the fruits of *D. glabra* while 24.3% use the rest of the plants as part of their diet.

The study found that harvesting wild fruits was a daily activity undertaken by men, women and children among the Boni community. This formed a large part of their daily diet. Alcohol was made from some of the fruits collected from the wild. The study also noted that the Boni community was quite proficient at making a variety of medicinal concoctions from the plants in the forest. These were made either from the leaves, bark, roots, fruits, flowers and even seeds.

The study found out that due to an increase in population specifically among the Boni community and the frequency of the dry seasons, some plants were over harvested and faced complete destruction in the near future. Some of the species had to be protected due to their role as sources of food.

In a bid to establish the role of the community in promoting conservation of Boni Forest, a number of questions in the questionnaire sought anwsers to and found out that the community embraced community policing, response to fire alerts, effectively educating children on the need to conserve the forest, controlling fire and controlling overharvesting of forest products particularly wood. Song and dance formed a means of passing on messages of conservation to the next generation. The study also noted the presence of many youth trained as forest guards who continually patrolled the forest.

Table 4.26: Species occurring as food/fruits in the study area

Species	Scientific name	Part Consumed	Season Consumed	Area	Forest or Rangeland
Mkalakaba	*B. cathatica*	Fruits/Stem	Dry/Wet season	Bodhai	Forest
Horo (hurub)	*D. glabra*	Fruits	Dry Season	Mangai	
Werek, mtongi	*T. africanum*	Fruits	Dry Season	Mangai	
Sheshone	*K. africana*	Fruits	Dry Season	Sankuri	
Karuk	*E. bakeri*	Fruits	Wet Season	Sankuri	Forest
Tumur	*U. acuminata*	Fruits	Wet Season	Mangai	Forest
Dabe	*V. glomerata*	Fruits	Wet Season	Mangai	Forest
Mburey	*F. indica*	Fruits	Dry Season	Bodhai	Forest
Olop (Hurub)	*D. glabra*	Fruits	Dry Season	Mongai	Forest
Kulamik	*C. triflora*	Fruits	Dry Seasons	Mangai	Forest
Dik (Deka)	*G. tenax*	Tuber	Dry Season	Sankuri	Forest
Ndoo	*P. ulhilingii*	Fruit	Dry Season	Sankuri	Forest
Kama (sha)	*G. villosa*	Stem	Dry Season	Mangai	Forest
Kuleb	*Z. chalybeum*	Stem	Dry Season	Milimani	Forest
Garas	*D. glabra*	Fruits	Wet Season	Bothai	Forest
Digi	*L. kirkii*	Fruits	Wet season		
Warde	*M. mochisisa*	Fruits	Wet Season	Bothai	

Banyorbi	*A. precatorius*	Leaves	Dry	Milimani	Forest
Chona	*L. fraxi*	Fruits	Wet	Bodhai	Forest
Jalmaley , Gorguo	*H. opposita*	Leaves, fruits	Wet	Milimani	Forest
Tielle	*E. hilderbrandhi*	Fruits, seeds	Dry	Milimani	Forest
Kurag	*M. sulcata*	Fruits	Wet	Bodhai	Forest
Halas	*U. lucida*	Fruits	Wet/ dry	Mongai	Forest
Mkaligote	*V.ferinossa*	Fruits	Dry/ wet	Mangai	Forest
Medi	*H. compessa*	Nut/fruits	Dry	Sankuri	Forest
Tomorr	*U. acuminate*	Fruits	Wet	Sankuri	Forest
Sheshubla	*D. orientale*	Fruits	Dry	Mangai	Forest
Ong	*B. aethiopicum*	Nut/ fruits	Dry/wet	Mangai	Forest
Kokonya	*C. nilotica*	Firewood	Dry Season	Bodhai	Forest
Nothake	*C. sepiaria*	Roots for chest cold	Dry Season	Mangai	Forest
Keunya	*C. farinose*	Roots for STD	Dry Season	Mangai	Forest
Ong	*B.s aethiopum*	Fruits edible/Weaving/basketry	Wet Season	Sankuri	Forest
Kiling	*B. wilsoniana*	Building (vulnerable)	Wet Season	Sankuri	Forest
Mgagini	*A. asterias*	Building poles	Wet Season	Mangai	Forest
Mfret	*A.s dimidiate*	Building/firewood	Dry Season	Mangai	Forest
Ban-yorboi	*A. precatorius*	Roots for gonorrhea	Dry Season	Bodhai	Forest

Keborr	*C. kirkii*	Leaves disinfectant for wounds	Dry Season	Bodhai	Forest
Mugurure	*C. schumannii*	Timber & wood carving	Dry Season	Mangai	Forest
Atame	*C. zimmermannii*	Building/firewood	Dry Season	Mangai	Forest
Msingoni	*D. cinerea*	Making cattle bomas	Wet Season	Sankuri	Forest
Mrongoleh	*E.capensis*	Building	Wet Season	Sankuri	Forest
Vugu	*E. sacleuxii*	Wood for making drums	Wet Season	Mangai	Forest
Kina	*E. suaveolens*	Building/ Tannin/Dye	Dry Season	Mangai	Forest
Maoth	*E. natalensis*	Dye from roots & bark	Dry Season	Bodhai	Forest
Kurahi	*F. magnifica*	Roots for chest ailment	Dry Seasons	Mongai	Forest
Kurkoi	*G. ternifolia*	Fruits for eye treatment	Dry Season	Mangai	Forest
Madiddi	*G. latifolia*	Bark fibre for ropes	Dry Season	Sankuri	Forest
Babbara	*J. palmate*	Stomach medicine	Dry Season	Sankuri	Forest
Babbara	*J. palmate*	Stomach medicine	Dry Season	Mangai	Forest
Komochi	*L. inermis*	Dye & perfume	Wet Season	Milimani	Forest
Safara	*M. stenopetala*	Roots medicinal	Wet season	Bothai	Forest
Tuari	*N. erlangeri*	Building poles	Wet Season	Milimani	Forest
Mbauri	*O. somalensis*	Building/Medicinal	Dry	Bothai	Forest
Mawacha ndovu	*O. spinosa*	Fruits edible/wood for furniture	Wet	Milimani	Forest
Mpotsho ndovu	*O. kirkii*	Leaves for headaches	Wet	Bodhai	Forest

Gonyoorriya	*P. reclinata*	Weaving/basketry/building	Dry	Milimani	Forest
Kihere	*R. mombasiana*	Malaria treatment	Wet	Milimani	Forest
Bullabulla	*R. ilicifolia*	Good timber	Wet/ dry	Bodhai	Forest
Darab	*S. africana*	Bark fibre for strings	Dry/ wet	Mongai	Forest
Leh-heli	*T. kilimandscharica*	Good timber	Dry	Mangai	Forest
Mlambale	*T. danis*	Stems for rungus, bows & arrows	Wet	Sankuri	Forest

Jah	*A. Digitata*	Fruits & leaves edible	Dry Season	Bodhai	Forest
Mlamote	*A.senegalensis*	Fruits edible/medicinal	Dry Season	Mangai	Forest
Mulilago	*A. venosum*	Fruits edible	Dry Season	Mangai	Forest
Ong	*B. aethiopum*	Fruits edible/Weaving/basketry	Wet Season	Sankuri	Forest
Abubeu	*B. cathartica*	Fruits edible	Wet Season	Sankuri	Forest
Mulimuli	*C. edulis*	Fruits edible	Wet Season	Mangai	Forest
Sheshuba	*D. orientale*	Fruits edible	Dry Season	Mangai	Forest

Hurub	*D. glabra*	Fruits edible	Dry Season	Bodhai	Forest
Kurrawa	*D. abyssinica*	Fruits edible/Roots anti VD	Dry Season	Bodhai	Forest
Tielle	*E. hildebrandtii*	Fruits edible in dry season	Dry Season	Mangai	Forest
Waharr	*L. schweinfurthii*	Fruits edible/medicinal	Dry Season	Mangai	Forest
Kukadshi	*M. aethiopicum*	Fruits edible	Wet Season	Sankuri	Forest
Mawacha ndovu	*O. spinosa*	Fruits edible/wood for furniture	Wet Season	Sankuri	Forest
Idamudu	*R. natalensis*	Fruits edible	Wet Season	Mangai	Forest
Tsina	*S. myrtina*	Fruits edible	Dry Season	Mangai	Forest
Mtongi	*T. africanum*	Roots edible after cooking	Dry Season	Bodhai	Forest
Tomorr	*U. acuminate*	Fruits edible	Dry Seasons	Mongai	Forest
Halas	*U. denhardtiana*	Fruits edible	Dry Season	Mangai	Forest
Mkaligote	*V. ferruginea*	Fruits edible	Dry Season	Sankuri	Forest

4.10.14 Indigenous knowledge systemson forest and water harvesting

The Somali had indigenous knowledge systems which they used to accurately position water pans. A number of incidents were narrated where such advice was ignored by development workers to their own peril. Such knowledge comes with years of experimenting and accumulating practical knowledge. It also had to do with knowledge of certain species of plants with high affinity for water thus reflecting proximity of the water table. A cluster of healthy trees together in an area denotes proximity to the water table. Traditional water harvesting structures too were also habitats for a variety of species. In view of accelerating biological and cultural landscape degradation, a better understanding of interactions between landscapes and the cultural forces driving them is essential for their sustainable management. The Somali and Boni communities derive a variety of goods and services from the Forest which means that the Forest holds great value to them.

Some of the benefits local communities identify with forest resources are shown in Table 4.29. The fact that these trees were also known by local names is an indication that they were of great importance and value to the community.

The Somali community in the study area was largely pastoralist and relied on the forest for both pasture and medicinal products for treating livestock diseases. The responses given by a cross section of the community that was interviewed to find outplant species used for treating livestock diseases showed a variety of ethnobotanical uses that were an indication of the value of the trees to the community (Table 4.27).

Table 4.27: Plant species used for treating livestock diseases

Species	**Scientific name**	**Plant part used**	**Diseases/Conditions it treats**	**Name of the Area obtained**	**Forest or Rangeland**
Abuthu	*P. amboniana*	Bark & leaves	Smoke repels Tsetse fly	Milimani	Forest
Abuthu	*P. amboniana*	Leaves	Treats Swollen stomach	Milimani	Forest
Agudhi	*O. kilimandseharicum*	Leaves	Swellings on livestock/stomach condition	Milimani	Forest
Agudhi (B)	*O. kilimandseharicum*	Leaves	Swellings	Milimani	Forest
Aworzi (B)	*B. huilensis*	Leaves	Repels tsetse flies	Roka, Boni	Forest
Abodi (B)	*P. amboniana*	Leaves	Leaves treat swollen stomach	Milimani	Forest
Garas	*Dobera glabra*	Resins in the leaves	Removes placenta if stuck	Bothai	Forest

The Somali community believe that the forest was established as a source of medicine for their livestock. From the focus group discussions, the community gave the following ways for treating various livestock diseases: feeding animals with saline containing plants such as *A. precatorius* (Banyorbi) leaves, *C. rotundifolia* (Har- komoro) ripe fruits and leaves, *D. orientalis* flesh stems and leaves, *S. persica* (Ade, adhei) fresh branches and leaves and *S. gillettii* (Dananiu) bark and leaves used raw. This diet ensures that ticks fall off. Abudhu (Abodi) and Aworzi (*P. amboniana B. huilensis*) roots, bark and stem are dried and ground into powder, put on burning charcoal to produce smoke which repels tsetse flies from livestock. The focus group discussions also corroborated the use of plant species such as *P. amboniana, D. glabra and O. kilimandschericum* to treat livestock diseases. Women and children picked ticks from the animals and threw them into fire; burnt infested pasture, acquired critical knowledge of the infested sites and avoided them. Witchcraft was reported to be effective in restoring animals to perfect health. Indigenous disease control measures were also carried out through herd management such as herd dispersion which was used to reduce the risk of infecting all animals belonging to one household.

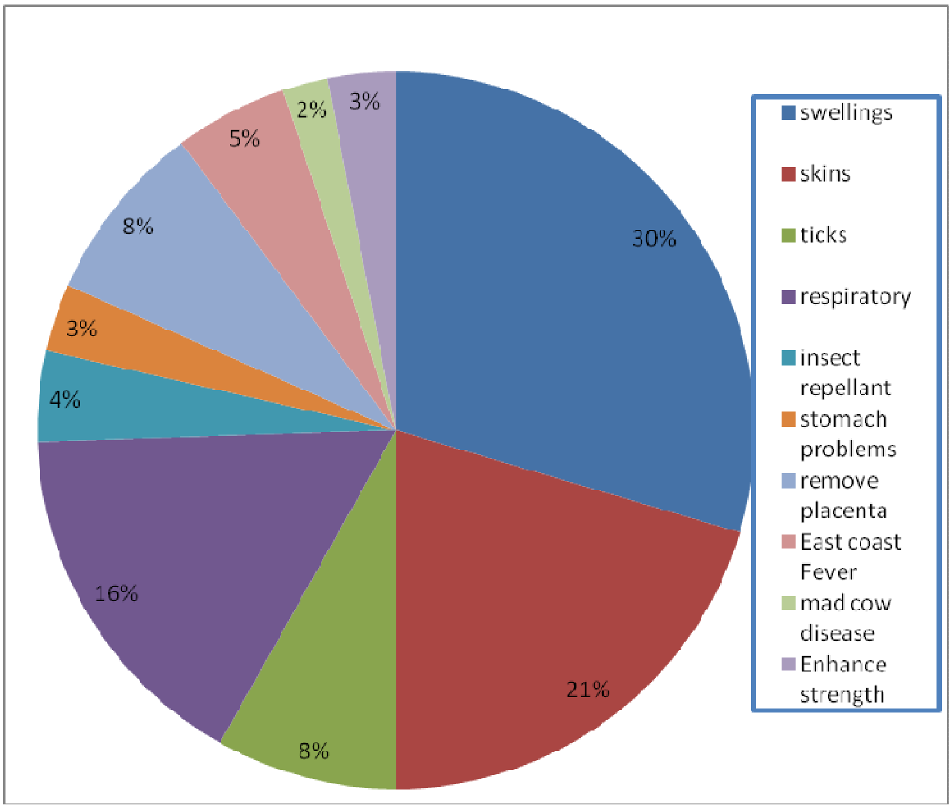


Figure 4.12: The percentage use of plant species for treating animal diseases

Table 4.28: Plant species conserved due to their role as sources of food

Botanical name	**Local name (Boni)**	**Economic uses**
A.digitata	Jah	Fruits & leaves edible
A. senegalensis	Mlamote	Fruits edible/medicinal
A. venosum	Mulilago	Fruits edible
B. aethiopum	Ong	Fruits edible/Weaving/basketry
B. cathartica	Abubeu	Fruits edible
C. edulis	Mulimuli	Fruits edible
D. orientale	Sheshuba	Fruits edible
D. glabra	Hurub	Fruits edible
D. abyssinica	Kurrawa	Fruits edible/Roots anti VD
E.hildebrandtii	Tielle	Fruits edible in dry season
L. schweinfurthii	Waharr	Fruits edible/medicinal
M. aethiopicum	Kukadshi	Fruits edible
O. spinosa	Mawacha ndovu	Fruits edible/wood for furniture
R. natalensis	Idamudu	Fruits edible
S. myrtina	Tsina	Fruits edible
T. africanum	Mtongi	Roots edible after cooking
U. acuminate	Tomorr	Fruits edible
U. denhardtiana	Halas	Fruits edible
V. ferruginea	Mkaligote	Fruits edible

4.10.15 Acquisition, storage and passing on of IKS

In a bid to establish the acquisition of IKS, an item was included in the questionnaire which sought for information on how and from whom the respondents initially acquired IKS (Table 4.29).

Table 4.29: IKS Acquisition

How/Person	Frequency	Percentage
Grandparents	57	81.4
Parents	56	80.0
Folklore	20	28.5
Apprentice	10	14.3
General observation in the community	26	37.1
Documentation and storage in libraries	2	2.9
Learning by doing	20	28.5

81.4% of the respondents said they acquired indigenous knowledge systems from their grandparents while 80% acquired it from their own parents. 28.5% acquired indigenous knowledge systems from folklore. A similar percentage said they acquired it from learning by doing while 37.5 % said they acquired it through general observation of the wider community members. A small percentage acquired it through apprenticeship.

Table 4.30: People consulted on IKS herbal medicine

People Consulted	Frequency	Percentage
Elders	48	68.6
Parents	22	31.4
Grandparents	16	22.8
Neighbours	13	18.6
Documented IKS	3	4.3
Community IKS specialists	9	12.9

68.6% of the respondents indicated that they consulted elders on the use of herbal medicine while 31.4% consulted their parents on which herbs to use when ill. 22.8% said that they consulted their grandparents on which plant species to use when unwell. Community indigenous knowledge systems experts were consulted by 12.9% of the respondents.

The study noted that indigenous knowledge systems were mainly passed on through stories, legends, folklore, rituals, songs and laws. Indigenous knowledge was obtained through experience and experimentation. It was evident from the focus group discussions with those who seemed to be the leaders that long-term experimentation and experience form the bedrock of consolidating positions on both current and older knowledge. From discussions with the elderly people, indigenous knowledge systems also encompass the social reality, cultural practices, values and traditions of the people. The study noted that 100% of the respondents did not belong to any group dealing with IKS like Traditional Health Practitioners. The Boni expressed a desire to join networks of traditional medicine medicinal plants (TMMP) which were quite strong in other parts of the country especially in the Rift Valley and which were receiving support from development partners and the Government. This would enable them to participate with other communities in the area of exchange of resources and experiences and knowledge. At the time of the study they did not belong to any networks. This would provide an opening for diversification and also options for developing learning programmes. The study encouraged the Boni to join the Herbal Medical Practitioners at the Coast.

4.10.16 Threats to indigenous knowledge systems

In order to establish the threats to indigenous knowledge systems for conservation of the forest, an item was included in the questionnaire to track the causative factors eroding indigenous knowledge systems and make recommendations to assist resolve the issue.

Table 4.31: Causes for decline of IKS use on plant utilization and biodiversity conservation

Causes	**Frequency**	**Percentage**
Lack of policies to facilitate wide IKS use	19	19.0
IKS not being adequately passed on to next generation	28	28.0
IKS not documented	12	12.0
Effects of colonization	7	7.0
Religion	34	34.0
Total	100	100

34.0% of the respondents said that religion was the single most significant cause of decline of use of indigenous knowledge systems for biodiversity conservation. 28.0% said that there were inadequate structures to facilitate passing on of indigenous knowledge systems to the next generation. 12.0% reckoned the declining use of indigenous knowledge systems for plant utilization and biodiversity conservation was occassioned by lack of documentation of this fundamental knowledge while 7.0% blamed the loss of IKS on persistent effects of colonization.

The study documented the following threats to indigenous knowledge systems among the Somali and the Boni.

Table 4.32: Threats to indigenous knowledge systems among the Somali and the Boni

Threats to IKS	**Causative perception**
a) Inadequate systems for mentoring the next generation;	Lack of mentors causes risk of IKS disappearing as the younger generation receives no education from the older generation. The systems that worked before are not known to the younger generation besides there being no time to sit around the fire place perhaps in the evenings to mentor the young people.
b) Lack of documentation;	IKS systems in rural communities are rarely documented. Thus, should the method of preservation and perpetuation be disrupted, there is a risk that within one generation, the knowledge could be lost forever.
c) Policy gap;	Current Policy in Kenya does not largely promote documentation of IKS. There is a role that policy can play to ensure that IKS is documented.
d) Colonial legacy;	The introduction of modern education and a new culture and new ways of doing things when Kenya was colonized by the British is largely blamed for the way most tribal groups have abandoned their indigenous knowledge systems to embrace foreign ideas and behavior including certain cultural value systems.
e) Formal education;	Formal education brings with it different perspectives and understandings which cause a whole generation to begin questioning most of the belief systems and cultures that tied a community together with the result of weakening the IKS fabric.
f) Religious influence	Religion is largely to blame for the weakening faith in the IKS systems.

These factors were rated among the communities (Table 4.32) and it was noted that among the Somali community, religious influence was the greatest hindrance to the passage of IKS from one generation to another. Among the Boni, a weakening system of mentoring youths was linked to the influx of outsiders into the area who tended to offer the youth more attractive past times accompanied by cash flows however inconsequential, education of children which erodes their traditional values leading them to question some of the myths and folklore and the lack of documentation of IKS were the main factors that caused a decline in passage of age old IKS from one generation to another. This loss was bemoaned by the elders but completely of no effect to the youth signifying the dire need to hasten documentation of IKS.

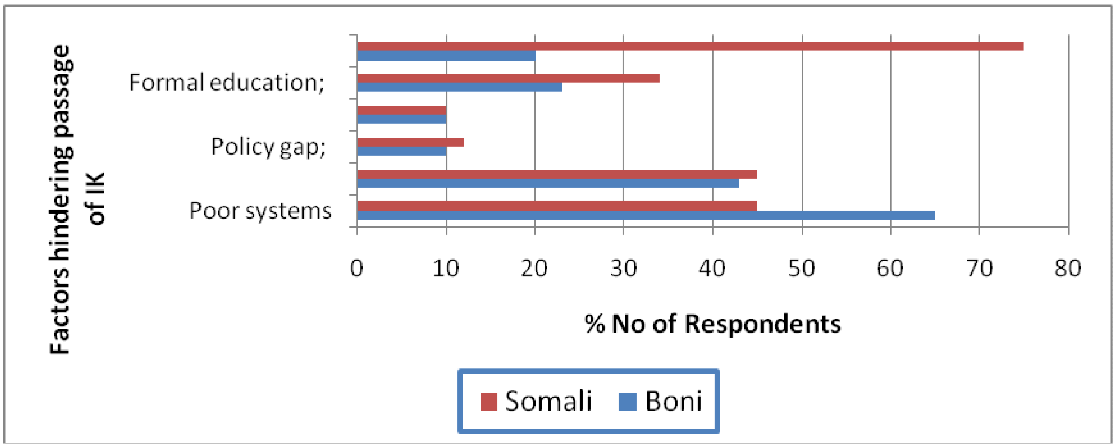


Figure 4.13: Factors hindering dissemination of IKS

4.10.17 Passing IKS to children among communities

The study identified that a number of methods are used to pass indigenous knowledge systems to the next generation. IKS was passed on through oral methods via grandparents, parents, apprenticeship, general observation, folklore and learning by doing. The study ascertained that indigenous knowledge systems was more often passed on by means of apprenticeship from the older to the younger generation than by any other means. This occurred during the hunting and gathering trips in the forests. As the older generation passes on, the knowledge goes with them as they are the main custodians of this information

4.11 Local Communities ideas for preservation of indigenous knowledge systems

Respondents gave a number of suggestions on how IKS on conservation can be preserved by the community. Table 4.33 presents the findings.

Table 4.33: IKS preservation techniques in the community

IKS preservation Techniques	Frequency	Percentage
Policy development	19	19.0
Incorporate IKS in formal Learning	41	41.0
Document IKS	20	20.0
Others	10	10.0
Declined to respond/Non committal	10	10.0
Total	100	100

19.0% of the respondents thought that indigenous knowledge systems could be preserved through development of relevant policies that would be used to both regulate and spell out mechanisms for preservation amidst provision of funds through an established governmental system. 41.0% of those interviewed said that incorporating indigenous knowledge systems into formal learning would ensure preservation of the knowledge to posterity while 20.0% pushed for documentation of indigenous knowledge systems as the most certain mechanism of ensuring that these unique processes and systems of naming plants, preserving them and utilization patterns are preserved. 10.0% were non committal.

4.11.1 Support required to enhance the value of IKS in development

The study found out that the support required in enhancing utilization of medicinal and food plant species among the Boni, included: infrastructure, product development, market access, benefit sharing, training (harvesting techniques), equipment and financial resources.The study observed that there are no private or communal seed banks for valued species in the area. This is a need that will enhance seed security for these communities. In terms of protection of resources, the traditional approaches used to protect useful plants, forests and water sources included no cultivation in the forest, no burning of vegetation.

4.11.2 A comparative analysis of threats and use of IKS for conservation

A comparative analysis of the threats to Boni forest and the application of indigenous knowledge systemswas conducted by treating single variables using a Kruskal-Wallis statistical procedure to all selected variables. The variables selected were: sacred species protected, sacred groves, grazing areas, communal or private seed banks and the woody species.A significant difference was found in all six transects with a significance of 0.021 for sacred species protected, special interest areas protected such as sacred groves, grazing areas protected such as the demarcated grazing refuge zones used during drought, communal or private seed banks available, and the total woody species. A pairwise Mann-Whitney test was conducted between the variables which passed the Kruskal-Wallis Test. Significant differences were found between treatments as shown in Table 4.37. All three components passed a Kruskal-Wallis Test (<0.001, <0.028, <0.001 and <0.011 respectively) and pair wise Mann-Whitney Tests were conducted between treatments, with significance values, between traditional techniques for harvesting and Boni forest threat and woody species <0.001, between special interest areas protected and threats to environmental sub component and woody species (0.028), between grazing areas protected and agricultural practices and woody species (<0.001) and lastly sacred species protected and Boni forest threat and woody species (<0.011). The figures show the significant differences and they both show that there was a positive relationship of the parameters being tested.

Table 3.34: Mann –Whitney test results comparing threats and conservation by IKS

Comparison	**Results**
Traditional techniques for harvesting and Boni forest threat	Woody species (<0.001)
Between special interest areas protected and threats to environmental sub component	Woody species (0.028)
Between grazing areas protected and agricultural practices	Woody species (<0.001)
Sacred species protected and Boni forest threat	Woody species (<0.011)

The analysis showed that the woody species significantly changed moving both to and from human settlement and where agricultural practices are undertaken having significant threat from farming activities on environmental subcomponents. A Pearson's Correlation statistic between threats on environmental subcomponent and the human settlement in Boni forest vicinity within the study area was negative and was strongest in the 5th transect and 2nd transect having -.364 and -.341 respectively at 95% confidence interval. The weakest Pearson correlation of 0.13 was in the 1st transect which had traces of indicators of the presence of wild animals such as buffalo dung and prints as well as traces of fire out break. Thus, the threats on Boni forest and human settlement were correlated in the agricultural practices treatment, implying that some woody tree species were heavily impacted under this regime. As compared to those between grazing areas protected and agricultural practices and sacred species protected as undertaken along transects where forest users utilize the forest in being guided by their indigenous knowledge systems.

Table 4.35: Spearman's test correlating threats and use of IKS in forest conservation

Variable	**Correlation coefficient**	**Threats on environmental subcomponent**	**Grazing system**	**IKS in forest use**
Threats on environmental subcomponent	Correlation Coefficient	1.000	0.383**	.053
	Sig. (2-tailed)		.335	.543
	N	136	136	136
Settlement in Boni forest vicinity	Correlation Coefficient	.383**	1.000	-.364**
	Sig. (2-tailed)	.335		.459
	N	136	136	136
Use of indigenous knowledge systems in forest use	Correlation Coefficient	.053	-.364**	1.000
	Sig. (2-tailed)	.543	.459	
	N	136	136	136

*** Correlation is significant at the 0.05 level (2-tailed), N: - Is the sample size*

Decline of plant species due to over utilization was tracked through observation and response to a number of questions to the selected segment of the community. A number of those asked indicated that they had noted decline in the availability of useful plant species in the forest and the analysis is presented in Table 4.36. All the respondents indicated they have access to the forest. Medicinal plants, plant species used for fuel wood, building and for food were cited as having declined over a period of time. This was indicated by the distance people had to cover inorder to collect the plants compared to their ready availability in the past. Those cited to have declined to an alarming state were mainly those used for food especially during the drought years. The respondents also noted that very durable trees used for building were no longer readily available. During focus group discussions, they readily acknowledged that it was not possible for outsiders to saw timber without their knowledge therefore implying that there were those from within colluding with timber merchants to disenfranchise the rest of the community through illegal logging of the most precious timber species. The study also through observation noted potential health hazards from the use of a number of plant species for low quality cooking fuels such as wood fuel and charcoal (in Masalani centre) and the inefficient combustion characteristic of solid fuels and the open fire or traditional stove indoors which result in dangerous combination of air pollutants, predominantly carbon monoxide and other small particles.

Table 4.36: Decline of useful plant species

Noted decline	Medicinal plants used and part	Plant species used as fuel wood	Plant species used in building	Plant species used for food	Declined
3	*F. indica* (mbarey) (roots)	*M.mochisia* (warde)	*G. plagiophylla* (harori)	*D. glabra* (hurub)	Found very far
2	*K. africana* (sheshole) (fruits)	*M. sulcata* (kuragi)	*T. pruniodes* (korobo)	*U. acuminata* (tomorr) Flacourtia indica (mburey)	Found far
3	*V. glomerata* (dabe) (roots)	*T. spinosa* (hareri)	*D. cornii* (kolati gurati)	*G. tenax* (daka)	Found very far
2	*U. lucida*(halas) (roots)	*L. bussei* (ina eh leh)	*H. compresa* (medi)	*G. villosa* (kamal)	Found far
2	*U. acuminate* (tomor) (leaves, roots)	*N.hilblebrandtii* (muwarale)	*A. venosa* (mulilago)	*B. cathatica* (mkalakaba)	Found far
2	*E. hildebrandtii* (tielle) (roots)	*C. africana* (mlange)	*N. erlangeri* (tuari)	*A. vinosa* (mulilago)	Found far
3	*D. glabra* (garas) (stem, roots)	*G. tenax* (kamal)	.urahi)	*H. compressa* (medi)	Found very far
2	*B. cathatica* (mkalakaba) (roots, stem)	*T. indica* (morhoqa)	*C. nilotica* (kokonye)	*V. glomerata* (dabe)	Found far
3		*H. inopleum* (tokohoji)	*Suregada* .(balmut)	*E. hildebrandtii* (tielle)	Found very far
3		*B. huilensis* (avudi, aworzi)	*T. danis* (mlambale)	*M. sulkata* (kuragi)	Found very far
1		*G. plagiophylla* (harori)	*C. pseudopulchellus* (barranad)		

Code: 1=available but not like before; 2=available but found very far unlike before; 3=no longer readily available

CHAPTER FIVE:DISCUSSION

The goal of the research study was to assess the status of the forest vegetation and document the indigenous knowledge systems for conservation of the biological diversity in Boni forest. In order to systematically study and analyze the situation, the research revolved around the four major objectivesoutlined in Section 1.5. This section of the work therefore consolidates all the results into a coherent discussion of the research and brings together a number of thoughts, explanations and reasonings as to why the results are what they are and compares with other research findings nationally, regionally and internationally.

5.1 GEOGRAPHIC LOCATION

The study units referred to as transects were located in the following areas: Mararani, Mangai, Bodhai, Sankuri, Hulugho and Sangailu. These were of great significance as shown by the unique features found in each area typifying diversity in vegetation and by inference in biodiversity. Mararani area is located in Boni Forest reserve on the southern side of Ijara Sub County and comprised of vegetation that was largely coastal with a variety of species. The trees in Mararani formed a closed canopy. Mangai is located on the southern side of Ijara Sub County albeit outside the Boni Forest on the northern side and had similar vegetation to Mararani area. The coastal effect on the vegetation reduced slightly giving rise to *Acacia – Commiphora* woodland. This was the transect largely used by the Boni to access the forest. The Bodhai area is on the south western side of Ijara next to the riverine forest along the Tana River. The area comprised of closed canopy forests due to the riverine effects and adjacent coastal forests. Sankuri area is located in the Lungi block of Boni Forest and comprised a closed canopy while Hulugho is located in the northern side of Ijara Sub County where it was drier and comprised mainly of the *Acacia – Commiphora* woodland. Hulugho area had a high number of livestock and wildlife. Sangailu is located in the northern side of Ijara which was generally quite dry.

The study used these 6 units to determine species composition, diversity and abundance. Species diversity was affected by a variety of different processes which are documented in the results section. It was noted that some of them operate across all the 6 transects. Biological and physical interactions including human interactions were studied in these 6 units inorder to determine diversity. This is because interactions between species and their physical environment including anthropogenic effects have a significant effect on the total number of species within an area. The 6 transects represented both anthropogenic environments and ecosystems thus giving very good opportunity to study species diversity and change causative factors. The study therefore measured diversity not only as species number, but also by indices that consider measures of species relative abundance. This approach has been widely used by a number of researchers including Sax and Gaines (2003). The study contributed to documenting the number of species found in each of these transects therefore providing a baseline for future studies which will be able to deduce the net changes in each specific area. Threats to the integrity of the ecosystems were also studied using these same units. This is useful information which will assist in determining how diversity has changed at local scales. It is hoped that these 6 transects will form reference plots for other researchers.

5.2 SPECIES COMPOSITION

A total of 386 plant species representing 81 families were recorded in the study. Out of the plant species identified over 130 were trees, indicating that the forest harbours a large pool of species confirming some aspects of the coastal forests of Kenya which have been described as characterised by high species composition and big sized trees (WWF, 2012). The high number of species richness in the study areawas attributed to the coastal influence and the presence of a number of rivers and lakes in the forest that contribute to the growth of many species. Climatic, edaphic variability and anthropogenic activities are other factors associated with the difference in species richness. The forests were richer compared to the Mau Forest where Beentje (1994) listed only 60 tree species and 80 lianas. Moreover, the findings corroborate well with WWF (2012) that these forests are a rich ecosystem that should be conserved. There was a lot of undergrowth and lianas in some sites making it impenetrable. This was clear evidence of the biodiversity richness of these forests.

The study noted that the structure of the woody vegetation was not only reflected by the age structure of each individual species, but by the number of different species themselves and their individual characteristics. Another salient observation was that the growth forms of the different species determined the canopy cover of the forest, in height and in density. Significant to note was that these two parameters were of particular importance due to their effect on light penetration to the forest undergrowth and their effective arrangement of the fuel load and also on the interception and concentration of water around tree roots. The study found very old trees with large diameters in the middle of the forest presenting a most unexpected scene. The probability of sustaining multiple ecosystem functions increased with species richness, but this effect was largely modulated by attributes such as species evenness, composition and spatial pattern. Overall, the study found that model communities with high species richness, random spatial pattern and low evenness increased multifunctionality. Sasaki *et al*., (2013), studied the relationship between biodiversity and ecosystem functioning and noted that accumulated knowledge generally supports the idea that biodiversity promotes ecosystem functionality and stability, and thus contributes significantly to various ecosystem services. This is further corroborated by Knops *et al.*,(2006); and Naeem *et al*., (2009).

The most dominant family in this forest was *Mimosaceae* with a variety of members ranging from trees and woody shrubs to annuals. The second most dominant family was *Euphorbiaceae* which included the genus *Croton*, *Bridelia* and *Drypetes* among others. Other important families included, *Rubiaceae*, the coffee family, *Combretaceae* and *Papilionaceae.* Less common plant families included *Olacaceae, Icaceaceae, Rhamnaceae, Rhizophoraceae, Zamiaceae, Simaroubaceae, Verbanaceae* and *Zygophyllaceae*. Mimosaceae is a family that includes the genus *Acacia* described as having thorn trees with compound and pinnate leaves and commonly occurs in a variety of ecological conditions of Kenya especially the dry areas (Beentje, 1994). Members of this family have also been reported as highly adaptable to a variety of conditions and this makes them ideal for rehabilitation of degraded sites (Scott, 2013). Members of the family Euphorbiaceae have tannins and are of low potential as timber sources (Beentje, 1994) and this may explain their relative dominance status in the Boni forest. In this study, three legume families; mimosaceae, papilionaceae and caesalpinaceae were ranked 1st, 5th and 9th respectively indicating that legumes are abundant in the forest and their role as nitrogen fixers is also significant in determining the fertility of the forest soils. This agrees very well with results by Dilworth, (2008). The findings also mirror those from the Tana Flood Plain Forests which include areas of the Boni, Dondori, Lunghi, Lower Tana forest, Lango ya Samba Witu forest and the Tana delta. These particular forests provide a unique ecosystem that is found in the Northern limit of the Eastern Arc Mountains and the Coastal Forests biodiversity hotspot, riparian forests along the meandering course of the lower Tana River, (UNESCO, 2010). These lowland evergreen forests are patchy, of different succession stages, and are dependant on ground water supplied by the river. This is much the same as some sections of the Boni forest that are ever green and seemingly dependent on ground water. In the lower Tana forests, characteristic trees include *Ficus spp., P. reclinata, A. robusta, P. ilicifolia, B. unijugata, S. madagascariensis, D. mespiliformis, B. racemosa*and *M. obtsifolia* (Kokwaro, 1984, Robertson & Luke, 1993).

The study to a large extent through the plant composition survey provided reliable standardized data on the status and change in the distribution and relative frequency of a large number of plant species. The results were in agreement with the view that terrestrial ecosystems typically support three or more times as many vascular plant species as vertebrate animal species, thus plant species comprised a substantial proportion of Boni forest biological diversity (Canadell *et al.*, 2007). Concomitantly, plants typically comprise the greatest number of species of concern in most regions, both in terms of native species with populations at risk and non-native species that pose risks. Plant species richness and composition can be strong indicators of site condition, including the richness of other species groups (Gardner, 2012), and they are often closely correlated with the richness and composition of animal species.Greve *et al*, (2012) noted that areas with higher species richness often have higher productivity with more carbon fixation per unit area and per time as opposed to disturbed areas.

The study noted the difference in species composition per transect and these results agreed with McMaster (2005) who noted a number of factors that influence species richness in vascular plants. Such factors include altitude, latitude aspects and human activities.There is a strong inverse correlation in many groups between species richness and latitude in that the further an ecosystem is from the equator, the fewer the species, even when compensating for the reduced surface area in higher latitudes due to the spherical geometry of the earth.The work agrees with the conclusions reached by Pavoine & Bonsall, (2011) who concluded that tropical ecosystems have the highest species richness.

One of the reasons for this diversity is the variety of soils and climatic conditions (especially rainfall) across the forest, this was confirmed by MENR, (2002). These results agree very well with the results from other studies which conclude that local species richness is also influenced by ecological factors (Greve *et al*, 2012; McMaster, 2005). For example, species richness is often higher in areas with higher productivity (the amount of carbon fixed by photosynthesis per unit area per time) while disturbances such as fires, droughts, floods, and human activities can also affect species richness. In many plant communities, species richness is greatest at intermediate frequency and/or intensity of disturbance as defined by the intermediate disturbance hypothesis (Jody, 2011). This is because very frequent disturbance eliminates sensitive species, whereas very infrequent disturbance allows time for superior competitors to eliminate species that cannot compete. A comparative look at other coastal forests in eastern Africa points to the same heterogeneous mosaic of vegetation. Three very distinctive forest types, each with its-own special flora and fauna, make the Arabuko Sokoke.Approximately 600 species of plants are known at Arabuko-Sokoke, including 50 that are globally or nationally rare.

5.3 SPECIES DIVERSITY

Shannon-Weiner diversity indices were calibrated for each forest type using quantitative abundance data. Diversity and evenness varied widely between forest types. This index speaks about species richness (number of species) and evenness (species distribution) (Spellerberg, 2005). The larger the value of H' the greater the species diversity and vice versa. An ecosystem with H' value greater than 2 has been regarded as medium to high diversity in terms of species (Kumelachew, 2008). Boni forest has relatively high species diversity as indicated by the results of this study. Species noted to have contributed to high species diversity include: *C. constrictum, D. glabra, A. digitata, L. schweinfurthi, N. hildebrandtii,* and *C. pseudopulchellus.*Increasing species diversity frequently enhances ecosystem function.Simply put, maximum diversity (equitability or evenness) exists when individuals are of different species while minimum diversity exists when all individuals are of one species. The study therefore intimates that ecosystem function in Boni Forest is quite good as deduced from the high species diveristy recorded. From the findings on threats to Boni forest, there was no evidence of non –random loss of species. Non-random loss of species may cause losses of diversity for specific groups that have a relatively greater contribution to ecosystem functioning. These groups include dominant species (Bracken *et al*., 2008), subordinate species (Bracken & Low, 2012), and specific guilds (Tscharntke *et al*., 2008). Decimation of the forest was mainly through targeted clearance of the forest for agriculture and through illegal logging for specific trees. This implies that the forest species diversity remains constant for as long as this kind of pattern of destruction is in place. It was noted thatspecies with high sensitivity to environmental stress are often preferentially lost in response to environmental pressures such as habitat fragmentation and altered disturbance regimes as attested by (Smith & Knapp, 2003; Gonzalez & Loreau, 2009). The results compare favourably with results from other coastal forests of Eastern Africa which are considered to be a global biodiversity hotspot – an area of high species diversity and endemism that is under increasing threat. The study area, Boni forest falls within this spot and due tothe relatively small area of this hotspot, it faces high degree of threat as also noted by(Brooks *et al*., 2002) and the current criteria for inclusion in the Red List (IUCN, 2013), all, or at least most, of the endemics are candidate "threatened species". The study confirmed findings by other scholars who observed that the most predominant vegetation type of the Eastern African Coastal Forests is dry forests and it is also the most complex and variable forest vegetation type, with Legume (mainly, *Caesalpinoideae*) dominance and others as dry mixed forests (Burgess & Clarke, 2000). The Arabuko-Sokoke, Shimba Hills and Tana Forests of Kenya are part of this amazing chain of coastal forests. The Arabuko-Sokoke Forest is the largest single block of indigenous coastal remaining in East Africa.

5.4 SPECIES DOMINANCE

A variety of species were identified to be dominant based on the different aspects of dominance.However, no particular species indicated total dominance in terms of importance values. The index of dominance value in this study was relatively smaller compared to what has been found by other studies in other coastal forests implying that the probability of picking randomly two individuals belonging to the same species is very low or the probability that any species encountered at random would be a different species. Dominance by certain families was noted in the Boni Forest as discussed above. The lower the index value, the lower the dominance of a single or few species (Jorgensen & Fath, 2008).Kumelachew (2008) point out that the greater the value of index of dominance the lower the species diversity and vice versa in the scale of 0 to 1. The study has clearly reflected this.

Dominance was strongly influenced by ecological conditions more than human influence and forests towards the coast in the south direction had significantly different characteristics from those of the drier north. The forests of southern Ijara described as coastal forests were richer in biodiversity than those of the drier north. Similarly these forests had higher density in terms of number of trees per hectare, higher basal areas and height. This has previously been noted by WWF (2012). From the vertical structure curves which refer to the vertical differentiation of trees among canopiesand which are influenced by tree size, Boni forest indicated sustainability with a uniform distribution of individual trees among sizes specifically in the southern parts of the study area. Similar cases are found in (Hall, 2011).

The similarity in plant species in the different transects confirmed species associations in different sections of the study area. *A.digitata* and *D. cornii* were among the 10 most dominant trees in all the transects.These trees had large diameters and accounted for most of the basal area in the forest. Other dominant trees included *D. glabra, A. nilotica* and *S. persica* which occurred at least in three transects. In each transect, there was one dominant species or two co-dominating species and then a fair distribution of basal areas among a number of tree species.

There were a few deformed trees that accounted for exaggerated basal areas. Such deformed trees had higher diameters that influenced their relative dominance values. They included *N. erlangeri, L. scweinfurthii* and *D. glabra*. The sum of relative dominance indicated that it was only in transect 2 that the tree species had a fair distribution in terms of dominance. In the other transects, the 10 top listed most dominant species took up at least 90% of the total basal area. This indicated that there were only a few species that achieved large sizes in the forest. This is because Boni forest has high species diversity which favorably competes within the forest stand, and no species has extremely high dominance. Similar findings were realized by Dash (2001)in other forests. It therefore means that all species in the forest are significant and should be targeted for conservation.

Some species were of small size but constituted very many individuals (high population); while other species were few in number but of large sizes (large diameters). Looking at the two indicators of dominance, only a few species were identified as having both high relative dominance and relative abundance. Such tree species included *D. glabra* which was well ranked by the two indicators in transect 3, 5 and 6; and *B. huilensis* which was well ranked in transects 1 and 2. Therefore, these two species could be said to have been well conserved with the former being dominant in the drier forests of the northern part of the study area and the latter species dominating in the coastal forests of southern Ijara Sub County. *D.glabra* belongs to the family S*alvadoracea*. *Dobera* is a genus of two species both occurring in tropical Africa and one extending to India. *D. glabra* produces edible fruits and the seed is considered a typical 'famine-food'. The local communities treasure it immensely. The Boni reported that the tree tends to flourish during the dry season. Other studies have also shown that if rains are delayed or fail, the tree typically shows an enhanced production of new shoots, fruits and seeds and that in normal times, when rains are on time or abundant, *D. glabra* does not produce much fruit and seed. When the tree blooms and produces fruits abundantly, people think that a drought may very well be under way and hence fear that food may become scarce (Tsegaye *et al*., 2007). Although the importance of *D. glabra* was highly appreciated by the local people in terms of food source and livestock feed and its adaptability to the area, there are some critical problems regarding this valuable plant as mentioned by the local communities. Among many other problems the main one was that it was rare to find seedlings of *D. glabra*. Only old trees were available. This was an indication that the plant was highly endangered and that extinction of the plant in the near future was inevitable if nothing is done. This observation has also been documented in the Ogaden by Tsegaye *et al*., (2007). *B. huillensis* is a species of flowering plants in the Asteraceae family. The tree has very hard wood, which makes it ideal for charcoal burning. For many years the tree was Kenya's main source of fuel until the 1830s. It was still a popular fuel source among the local communities and was threatened by overexploitation which may cause habitat loss for endemic animal species. The wood is heavily exploited in the wood carving industries in Kenya. *B. huillensis* is near threatened according to IUCN (2013). *A. quanzensis* was also quite common in Boni forest. Acacia in the Tana flood plain forests include *A. elatior*, which is a dominant species accounting for 23.2% of the total basal area. The dominant tree species in the entire Arabuko-Sokoke are: *C. webberi, B. speciformis, A. quanzensis, H. verrucosa, J. magnistipulata* (Burgess & Clarke, 2000). There is therefore a measure of similarity between Boni forest and the Arabuko-Sokoke forest.

5.4.1 Species dominance by height

Species dominance by height is ideally a function of abundance and tree volume. Though the results showed that different tree species were emergent at different parts of Boni

Forest, *D. cornii* trees were ranked among the 10 tallest trees in four of the study locations namely transects 2, 3, 4 and 6 indicating that this tree was well distributed and appeared to be well suited to the state of the environment in a variety of ecological conditions and was therefore dominating in the top canopy. The tallest trees encoutered in the study had a height of 25m. Although transect 4 was expected to be similar to transect 1 and 2 (being of similar characterization, i.e., coastal forest as indicated in (WWF, 2012), there was a deviation in height in transect 4. Provisionally, this observation could be attributed to the removal of the tall trees due to selective logging of preferred timber tree species. It should be noted that in transect 4, trees like *A. digitata* and *D cornii* which have no commercial value (Beentje, 1994) were dominant. The soils of the southern parts of Ijara were well protected by the dense forests and thus more productive than those of the north, this was also indicated by (ALRMP, 2005). Vertical structure plays an important role in forest ecosystems (Fonseca *et al*., 2004; Schurr *et al.*, 2004). A species' relative dominance in a forest is a proxy value for that species' contribution to wood volume. Several studies have emphasized the role of habitat quality and habitat diversity in determining species occurrence. Greater extinction rates of some species in small forest fragments could be related to the change in quality and diversity of habitats (Dupre & Ehrlen, 2002; Jacquemyn *et al*., 2003; Kolb & Diekmann, 2004). The dominant tree species in the Shimba Hills forest are: *Scorodophloeus fischeri* (the western part), *Paramacrolobium coeruleum* (Kivumoni area) and *Erythrophleum sauveoleus* (Burges & Clarke, 2000). The number of woody tree species in terms of the heights are-tall trees, 152 species (10.9%); small trees, 207 species (14.8%); and Woody herbs, 172 species (12.3%) (Luke, 2005).

5.4.2 Species dominance by importance

Except for *D. glabra* that was best ranked in two transects (transect 5 and 6), specific species dominated at different study locations. The abundance of the woody shrub *C. pseudopulchellus* was noteworthy despite its small diameter size, the tree was highly ranked in transects 1 and 2. A pale white-yellow-flowered, shrubby, perennial plant with a sweet smell that attracts many insects, *C. pseudopulchellus* growsupto 4 m tall. It has a grey bark, smooth to roughish; branchlets reddish brown covered with hairy scales.*C. pseudopulchellus* is used as a source of traditional medicine as also recorded by Sindiga (1994). Among the Boni, the powder of the root bark is applied to syphilitic ulcers, while the concotion of root and leaf sap is drunk to treat asthma. The root powder and leaf concoction is drunk for the treatment of headache. The root powder is also used for the treatment of colds. Dried leaves are burnt, and the smoke is inhaled for the treatment of fever. Leaf concoction is rubbed on the chest for treatment of colds. Concoction of leafy twigs is drunk for the treatment of gonorrhoea. Its abundance means it is a plant of least concern in terms of its conservation status. This presents a potential threat to conservation of the forest because in as much as the plant species is abundant at present, it is not guaranteed that it will be the case in future because it is a finite natural resource, coupled with challenges presented by climate change. The plant is obviously used for many purposes meaning that it will be exploited more often to meet the needs of the community, this was observed by (Alonso, 2008). The community should endevour to conserve the plant in this regard.

A.digitata, despite being low in numbers, its large diameter enhanced its dominance leading to its high importance values in transect 4. The dominance of *D. glabra* in transect 5 and 6 was conspicuous and surpassed the second dominant tree species with an importance value of over 10 units. This was because of the presence of the tree species in both big sizes and large numbers, together with wide distribution in transects 5 and 6. The importance value index provides knowledge on important species of a plant community.

In transect 2 and 4 there was no clear dominance among species and no significant difference in importance values indicated by a Kruskal Wallis Test at P< 0.0 (for testing whether samples originate from the same distribution*)* between the five best ranked species. The species in these areas tended to assume the conditions of a planted forest where the number of individual species has been moderated and the dominance in terms of basal areas also moderated hence uniformity in tree sizes. These findings agree with those of tree dominance by height which indicated that in transect 4, there was no clear emergent, and all trees tended to have uniform heights.

A summary of tree dominance by numbers, basal area, frequency of occurrence, crown diameter and tree height allows for a classification of the vegetation of Ijara forests into forest associations as described by Beentje (1994). These associations are based on the dominant tree species at different study sites. For example the drier forests of the north can be clearly defined as Acacia forest while the southern coastal forests have a mixture of species without a clear dominant species in all aspects of dominance tested. The overall dominance of species in the study area as described by the importance values indicates that the most dominant species are *D. Cornii, D glabra, A nilotica* and *C pseudopulchellus* in order of decreasing dominance.

A. nilotica is a tree 5–20 m high with a dense spheric crown, stems and branches usually dark to black coloured, fissured bark, grey-pinkish slash, exuding a reddish low quality gum. It is used as forage and fodder for small stock which consume the pods and leaves. Dried pods are particularly sought out by animals on rangelands. In the study area, it was noted that *A. nilotica* makes a good protective hedge because of its thorns. *A. nilotica* gum is used to treat otherwise watery semen. The tree's wood is very durable if water-seasoned and its uses include tool handles and lumber for boats.The wood has a density of about 1170 kg/m³ (Turril, 2007). The high importance value and relative dominance of the species means that conservation initiatives the community have applied ensure survival of the species. The benefits derived from the tree encourage its conservation which translates to preservation of the forest diversity.

The forests in the southern part of Ijara Sub County were moderately or well conserved and may not have been experiencing a great threat of degradation. Changhui (2000) intimated that a sustainable forest has a geometric progression from one tree size to another and a low exponential function explains a more sustainable forest because there is a uniform distribution of tree sizes and there is adequate regeneration to replace the mature trees that are either dying or being removed. These are characteristics identified with sustainable forests that have undergone several stages of succession (Changui, 2001; Vogt, 2007). Some of these forests may be described as pristine at the tertiary level of species succession where no individual species dominates as also demonstrated by (Vogt, 2007). A good explanation for the pristine condition of the forest was given by the security status of the area which inhibits exploitation. The presence of tsetse flies (*Glossina morsitans*) in sections of the forest had also inhibited grazing in some areas which helps the forest to regenerate without undue interference.

The forest had a high potential to support livelihoods by providing more forest products and at a sustainable level. Even though structure curves for a forest may indicate sustainability, this may not be the case for the individual tree species (Changhui, 2000).

Kinyanjui (2009) found out that, though structure curves for forests of Transmara district indicated sustainability, individual species like *M. butugi* were highly threatened.

The study observed that some non commercial trees like *C.pseudopulchellus* and *A. digitata* may have become dominant due to preferential non exploitation as compared to other species in similar study sites. Some of the dominant species identified in the vegetation surveys were not listed as important species for local use. For example, the family Euphorbiaceae which had a big number of individuals has only a few uses among the communities while rare trees like *T. spinosa* which are highly valued for timber have a high demand.Kinyanjui (2009) identified a case of preferential exploitation in Mau forest which resulted to dominance of some non commercial trees. In this case, exploitation of such commonly occurring species to support the livelihoods of the growing community should be sought. Kiyiapi (1999) proposed the commercial exploitation of the gregarious *T. ellipticus* in Transmara forest in order to reduce its abundance and facilitate the development of other species and therefore provide for basic needs of the community including fuelwood.

This study observed that the over extraction of the roots of *L. schweinfurthii* makes the species susceptible to overuse and it required measures that would allow for sustainable exploitation to be put in place. Other species that require conservation measures include *A. gumifera* valued for medicine including treating malaria and *A. reficiens* which has edible gum that can easily be exploited for commercial production, as also attested to by (Beentje, 1994). An exploration into the utilization of some of the forest products illustrates that gum Arabica which is largely exploited from the Acacia trees like *A. seyal*as found out by (Beentje, 1994) is highly marketable and would provide a source of income to enhance the livelihoods of the community. Demand for gum arabic has been constrained at times by the supply implying that there are potential markets even for communities from Boni to enter such world trade. The abundance of such trees makes them a sustainable source of income for the community which would be exploited to diversify production and reduce overreliance on agriculture. If the forests would provide more products of this nature (which is unlike logging that results in the total destruction of the tree), the communities would be motivated to further protect them and activities like fires and shifting cultivation which threaten some parts of the forest would be reduced. Gum arabic is a complex, slightly acidic polysaccharide (Singh, 2010). The precise chemical and molecular structure differs according to the botanical origin of the gum, and these differences are reflected in some of the analytical properties of the gum. As a result, the functional properties and uses to which gum arabic can be put (and its commercial value) are also very dependent on its origin.

The European Community is by far the biggest regional market for gum Arabica. In countries such as Kenya *A. senegal* does produce gum naturally and all of the gum which is collected comes from harvesting natural exudate (Singh, 2010). Total world gum arabica exports in 2008 were estimated at 60,000 tonnes, having recovered from 1987–1989 and 2003–2005 crises caused by the destruction of trees by the desert locust. According to a reuters report in February 2013, Sudan, Chad, and Nigeria (United Nations Conference on Trade and Development (UNCTD), 2013), which in 2007 together produced 95% of world exports (Laessing, 2013) and the demand is increasing (Gunn, 2013), implying that trade from Kenya is still at a very low scaleand that there is room and potential to exploit this market in future. Reports by Standard media on 27 August 2013 revealed that Kenya was losing billions of shillings to other gum producing countries, in particular Sudan, which earns more than 4 billion shillings every year in exports (Koigi, 2013). Sudan accounts for about 80 percent of gum production mostly supporting small producers in rural communities (World Bank, 2013).

The Boni can formalize Gum Arabic trade and intentionally nurture *A. senegal* in order to derive viable quantities of resins to meet local and international demand for the product. There is ready market for gum and the attendant products which means the community only needs to enhance production, quality, and collection so as to meet the expectations of local and international buyers, which will in turn fetch better profits and the much needed income for the locals. The community mostly collect the gum as a part time activity and have limited knowledge on economic potential for the plant or trends in market price (Wekesa, *et al*.,, 2013). The socioeconomic status of Boni community would improve if gum trade was taken as a serious economic activity as it would offer an alternative livelihood instead of the heavy reliance on forest products and the newly introduced agriculture. Ecological benefits will be realized and besides the species is effective in improving soil stability, fertility, and protection of the fragile ecosystem. In as much as the economic benefit will act as an incentive for conservation, care should be taken to avoid so much commercialization of gum Arabic that it would be threatened. This is because every economic activity on natural resources has spill-over costs and benefits (UNEP, 2013). The trade has potential to either promote conservation or degradation of the forest. In this case, sustainable management and utilization of the species is very important.

A. quanzensis and *T. spinosa* which are endemic to the coastal region (Beentje, 1994) require regulations of use. These are highly valued timber species and large scale exploitation can lead to their extinction especially due to their limited ecological range. *Afzelia* is a genus in the subfamily Caesalpinioideae of the family Fabaceae (legumes). *T. spinosa* is a native of north eastern Kenya into Somalia and the Ogaden region of Ethiopia. It is a spiny desert tree, growing to 15 meters. It is deciduous. Among the Somali, it is known as Hareri and is regarded as the best wood for bomas, movable houses and semi-permanent structures.Its hard, heavy, dark-brown wood is almost termite-proof and very durable. As the leaves are not normally consumed by goats, its potential as a live fence is great.*A. quanzensis* is known locally as *mkongo* or *mbambakofi*. In English the tree is known as the Spectacle Case tree, on account of the shape of the fruit. There are tall specimens growing to well over 20m in some patches of Boni forest. Mature specimens typically have a spreading canopy.During the dry season it is easily identifiable by the large, very woody, black pods. These remain on the tree after splitting in two to reveal the shiny black seeds inside that are nearly 3cm long. The seeds drop to the ground where their waxy orange cap (aril) is eaten by ants. At the start of the short rains in early November, as the tree comes into leaf, it produces fragrant green flowers with a reddish coloured upright flag petal and green outer ‘petals’ (sepals), giving the air around a spicy-sweet fragrance. The leaves are very glossy, almost evergreen and are typically made up of 7 or 9 large leaflets. Initially the treehas smooth, almost pinkish thin bark, but older specimens have thicker tan bark that peels off in large pieces. The warm, pink-tinged orange timber is locally used in furniture-making. It has a characteristic grain. The timber is too dense for many local uses but historically it was used for making traditional Zanzibar-style doors. The seeds are used as counters in board games e.g. *bao*.The study notes the invaluable ecological services and aesthetic value offered by *A. quanzensis* and recommends its conservation. As there are only patches of it in Boni forest, particular attention should be given to protect the species which will in turn sustain the health of the forest. Among the best-known plants in the ecoregion are the species of

African violets (*Saintpaulia spp.*), whose endemism is well documented. Also found here are 11 species of wild coffee, 8 of which are endemic.

Boni Forest is among the East African Coastal forests which as noted in WWF 2012 have long been isolated from other regions of tropical moist forests by expanses of drier savannas and grasslands, causing them to have an exceptionally high level of plant endemism that has recently led to part of it being classified as the Swahili Centre of endemism. The number of endemic species is thought to be greatly underestimated due to civil strife that has prevented further exploration. There are about 4,050 vascular plant species in the Coastal Forests of Eastern Africa Hotspot and approximately 1,750 (43 percent) of the plant species are endemic (WWF 2012). The hotspot holds at least 28 endemic plant genera, most of which are monotypic. About 70 percent of endemic species and 90 percent of endemic genera are found in forest habitats (WWF 2012). A good number of these endemics are found in patches of Boni forest as illustrated by the findings of this study.

The delineation between species of one ecological condition in Boni forest to another may not be very clear since a few species spread across different ecological conditions. Similarly variation in density is a reflection of environmental characteristics such as rainfall and soil types as well as effects of anthropogenic disturbance and herbivory. This results into distribution of species and species associations in the forest. This is relevant in proposing conservation measures and management practices as previously proposed by ALRMP (2005). The patterns can be useful to influence decisions as to which species to conserve and species for preferential exploitation in specific sections of the study area. By considering the use of these species, it is possible to propose sustainable management and conservation measures due to their relative abundance. Such species can be targeted for use by the community without the threat of being eliminated. Any species that spreads over different ecological conditions indicates high levels of adaptability and would be ideal for rehabilitation of degraded sites.

Other studies present a striking resemblance to the ones in Boni forest where the most dominant family in the forest was *Mimosaceae* with 12.4% of all species identified in the study belonging to this family (Table 4.2). The family *Mimosaceae* had a variety of members ranging from trees, woody shrubs to annuals. The second most dominant family was *Euphorbiaceae* with a species occurrence of 9.3% of the data for all plant families encountered in the study. The other important families included, *Rubiaceae*, the coffee family, *Combretaceae* and *Papilionaceae* accounting for 5.43%, 4.65% and 4.65% respectively of all the species recorded in the study area. Less common plant families included *Olacaceae, Icaceaceae, Rhamnaceae, Rhizophoraceae, Zamiaceae, Simaroubaceae, Verbanaceae* and *Zygophyllaceae* each of which had a species composition of less than 1% of all species recorded. The Shimba Hills Forests, forests of the lower Tana flood plains and the Arabuko Sokoke area has about 71 distinct forests, ranging in size from 1-1,100 ha and covering around 3,700 ha in total (Butynski & Mwangi, 1995). They form part of a mosaic of habitats that include grassland, wooded grassland, bushland and deciduous woodland. For example, when 15,538 stems of woody vegetation were measured in 71 sample plots along the Tana River, 101 species belonging to 46 families were identified. The families represented by the highest number of species are *Capparaceae* (11.9%), *Mimosaceae* (7.9%), *Euphorbiaceae* (6.9%), *Apocynaceae* (5.0%), and *Tiliaceae* (5.0%). On average, there are 19.3 species per plot (Maingi & Marsh, 2006). These results compare favourably with the findings in Boni forest.

Species that spread over different ecological conditions and are highly adaptable and ideal for rehabilitation of degraded sites have been recorded elsewhere in Kenya, for example, Kinyanjui (2009) identified *N. macrocalyx* as a gregarious colonizer in degraded patches of the Mau forest while Kiyiapi (1999) named *T. ellipticus* as a very abundant woody species in Transmara district forests and proposed an exploration into its commercial exploitation as previously stated above. Similar proposals are possible in Ijara Sub County considering the species of great abundance. Elsewhere, Jan *et al*., (1996) identified species like *C. elaeagnoides* and *T. grandis* as gregarious in Mexico and such species have been extensively grown to provide timber and save the slow growing valuable forest species. Similarly, the extensive growth of *P. juliflora* due to its gregarious characteristics (Geesing *et al*, 2004) has resulted to reclamation of deserts and although at local scales the tree has been associated with social problems (Choge, *et al*., 2002), the species has been allocated a wide variety of uses which preserves the formerly exploited species. Exploring the potential to quickly regenerate such species and cover the opened forests would be a solution for protecting the forests.

5.4.3 Basal area

The basal areas of the trees confirmed the tree density findings and indicated that the coastal forests (transect 1, 2 and 4) had better stocking than those of the drier areas. The best stocked forests were found in transect 1 with 36.75 m^2 ha^{-1} while the lowest stocking was in transect 5. A chi square test indicated a significant difference in the basal areas among these sites ($P<0.001$) and the difference was associated with the low basal area in transects 5 and 6. The forests of the south had a capacity to produce more and meet the livelihood needs of the communities while the forests of the north had low stocking, low species richness and require more conservation efforts.

The findings of good stocking in the forests of southern Ijara compared well to the findings of Blackett (1994) who studied the basal areas of several indigenous forests of Kenya. He found out that the Mau forest had a stocking of only 17 m^2 ha^{-1} and Kakamega forest had 26 m^2 ha^{-1}. Similarly, in a mature plantation of cypress whose stocking is 266 trees of an average 30 cm Dbh, the basal area is about 19 m^2 ha^{-1} based on a 30cm average Dbh and a spacing of 266 trees at harvesting (KIFCON, 1994). The better stocking in some of the study areas could be associated to better conservation of forests in Kenya since 1994 when Blackett did his study or it could be an indication of the efforts of conservation by the communities of Boni Forest. It should be noted that the high values of basal area could be associated to the very big trees of *A. digitata, D. glabra, N. erlangeri* and *L. scweinfurthii* which were identified in the forest. *A. digitata* commonly known as the African baobab tree is mostly known for its exceptional height and girth. The trunk tends to be bottle-shaped and can reach an impressive diameter of 10-14m and the tree can reach a height of 25m, the height of a 5 story building. The branches are thick, wide, and stout compared to the trunk, and can be spread evenly across the height of the tree, but are usually limited to the apex. The root system of *A. digitata*, while shallow, spreads further than the height of the tree, contributing to its ability to survive in dry climates. The range of the shallow root system allows the trees to collect and store massive amounts of water during the heavy, but infrequent rainfalls, which they then use to photosynthesize in the trunk during the 8 months in which they are leafless. This species is found to be among the most effective trees at preventing water loss. Every part of the African baobab tree has been used by humans for multiple purposes, including medicinally and nutritionally, however it is not widely cultivated (Ebert *et al.*, 2002).

Additionally, *N. erlangeri* is a species of legume in the Fabaceae family. It is found in Kenya, Somalia, and Tanzania and its status is near threatened (IUCN 2013).

L. schweinfurthii known as Wahari (Boni) is a small tree normally less than 10m high with a sticky, purplish, edible fruit. Though the wood is soft and light, it does find use as fuel, stools, mortars, and even for temporary building poles. The flaky grey bark is boiled and the extract used to treat paralysis and polio. Sometimes, it is drunk to ease abdominal pains in pregnant women, and leaves are boiled and used on the stomach to speed delivery. A dark red or brown dye is extracted from pounded bark, which is used to color sisal baskets. If sisal ropes or fishnets are boiled in water with bits of bark they will last longer.Its roots are shallow, often competing with food crops. From the roots a brown wooly insulating material is obtained and used for pillow and mattress stuffing. The plant is near threatened as well. In the Tana flood plain forests Maingi & Marsh, (2006) found that other species contributing to approximately 55% of the basal area are *S. venenifera (12.8%), C. sinensis (9.9%), D. loranthifolia (8.4%), S. persica (5.9%), M. obtusifolia (5.3%), E. natalensis(5.2%), H. zeylanica (4.0%), and C. goetzei* (4.0%). On average they found that in these flood plains, there can be 14.9 species observed per plot, and these occur at a density of approximately 3000 stems per ha and have a mean height of 4.4 m. The overstory has a density of 87 stems per ha and occurred at a mean height of 19.9 m, making it the tallest among all forest groups. *A. elatior* accounts for nearly half of the basal area in the overstory. Other dominant species in the overstory include *A. robusta*, *D. mespiliformis*, and *S.venenifera* (Maingi & Marsh, 2006).

5.4.4 Tree vertical structure curves

In terms of the vertical structure, forests of southern Ijara (transect, 1, 2, 3 and 4) had moderate reverse J curves as compared to those of the drier north. For example the exponential factors for the curves in transect 1 and 2 were 0.211 and 0.34 respectively compared to 0.86 and 0.943 in the curves of transects 6 and 5 respectively. According to Changhui (2002) moderate reverse J curves indicate a moderate geometric trend among diameter sizes in a forest and show a forest that is normal. On the other hand, a big exponential factor indicates that the small trees totally out number the big trees. A situation where the big trees are very few and there are many small sized trees is typical of disturbed conditions (Changui, 2000). While the distribution of trees per acre is reverse-J shaped, the distribution of basal area per acre is humped. The use of the reverse-J curve is a special case of *diameter regulation*, the idea that production can be sustained in an uneven-aged stand by maintaining a consistent residual distribution of sizes (and ages) of trees after each harvest. In this sense, the goals of diameter regulation are the same as those of volume regulation in a large, uneven-aged landscape composed of even-aged stands (Hall, 2011). A successful approach to diameter regulation would regulate the harvest, to ensure that overcutting does not occur; ensure sustainability, by providing for adequate regeneration and vigorous growth of the residual trees, prescribe stand structures that lead to desirable outcomes, including stability in site protection, positive habitat values, economic productivity and aesthetically attractive stands, including provision of a repeatable basis for experimental design (Ducey, 2009).

5.5 Forest Threats

A variety of threats were noted during the transect walks. From a pair wise comparison the major threats in the forest were identified as: (a) deforestation by shifting cultivation, (b) settlements in the forest area, (c) harvesting timber/logging, (d) grazing, (e) bush/forest fires and (f) illegal harvesting of building poles, in that order of priority. However, these differed within the study area and each of the threats is discussed below:

5.5.1 Deforestation through shifting agriculture

Results of the study showed that deforestation through shifting agriculture was an acute, pressing and urgent issue in the study area.From the respondents, a segmentation of the community was undertaken to indicate the common livelihood options and determine the main threats to the forest. An analysis of the drivers of specific livelihood strategies indicated that almost everyone was farming for purposes of food security and generating additional income for the family. The trees in Boni Forest were disappearing rapidly as farmers cleared the natural landscape to make room for farms and pasture. Trees are habitats and shelters to millions of species besides acting as filters of carbon dioxide, and also important for their aesthetic capital. The results are corroborated by a report by Kenya Forest Working Group (2011) which also revealed that trees in Boni Forest were being depleted at a very fast rate.

The study found out that the Bothai community comprising the Somali settled in the forest in 1991 and started rain fed farming. The main livelihood strategy was therefore farming. The farmers grew some vegetables in the farms next to the forest, which were often destroyed by wildlife. These included tomatoes, green grams and cowpeas. The type of vegetable to grow was determined by the season. The crop yield was sometimes very high but most households sold all their produce immediately after harvest leaving them vulnerable to food insecurity and impatient to begin the farming cycle again. This had deleterious effects on the biodiversity as some resorted to slash and burn to increase acreage and productivity.

In Bodhai, the farmers had put 50 hectares of forest land under different crops such as maize, which is the main crop, cowpeas, green grams, cassava, sim sim, paw paws and watermelons. The farmers had been farming in the forest for close to two decades by the time of the study. When further probed, the community was ready to intensify farming and introduce new crops such as millet and sorghum if the above constraints were addressed. The impacts of these activities to the Boni forest were dire. This was further exacerbated by the potential impact posed by the various ambitions of each farmer to expand acreage and production with the focus on decimating the forest. Conflicting government policies juxtaposed with limited knowledge of the total economic value of the forest multiply to confound issues of environmental concern vis-à-vis sustainable development.

In Mararani and Sankuri transects, the farming was not as pronounced as in the other transects but had the potential to escalate due to poor enforcement of environmental laws. The Mangai transect was impacted by slash and burn farming technologies practiced by a large cross section of the communities. Slash-and-burn farming, (Fearnside 1999, Steininger *et al*., 2001), is a serious cause of deforestation (Colchester, 1994; Sizer & Rice 1995). Deforestation caused by such fires leads to widespread forest/habitat fragmentation which has a myriad of environmental effects. For instance, in the Amazonian forests, it has altered the diversity and composition of forest biota, and changed ecological processes like pollination, nutrient cycling, and carbon storage (Kumar, 2012, Gardner, 2012, Laurance *et al*., 2002). Threat level distribution in relation to the dangers caused by fire enhances values threatened and promotes the suppression of regeneration level. Clearance for temporary cultivation plots not only transforms forest structure through cultivation itself, and through regrowth, but also through the selective removal of trees.

The farmer communities mainly grew vegetables in the farms next to the forest, comprising Pokomo and Bothai communities. Though historically, the Bothai kept livestock, they turned to farmimg due to high tsetse fly infestation despite the extensive pasture in the Forest. Subsistence farming includes growing of vegetables like tomatoes, green grams and cowpeas. The crop yield is sometimes very high but most households sell all their produce immediately after harvest leaving them vulnerable to food insecurity and impatient to begin the farming cycle again. It is this vicious cycle that has the potential to cause decimation of the forest at an alarming rate. This being a new livelihood among the Somali, there are no cultural values inherent in the activity and therefore no code of ethics or indigenous knowledge systems surrounding the use of land for agricultural practice with a keen eye for conservation of natural resources. Vegetable growing had deleterious effects on the biodiversity as some resorted to slash and burn farming methods to increase acreage and productivity. At the same time, this livelihood was seriously affected by the problem of wildlife crop destruction and the only ready remedy was to increase acreage which implied destruction of more forest land.

The farming households' were generally in charge of an average of 3 acres. The farms were situated in the middle of the forest 8 kilometers from the settlements despite wildlife menace. The results showed that men were the main users of forest products with livelihoods that decimate the forest, very much in tandem with the findings of Xasan, (2012). Sale of milk and weaving of handicrafts were activities for women while the youth were mainly involved in livestock rearing. The results implied that it was the men who posed the greatest threat to the forest through their livelihood activities such as farming, exploitation of traditional medicine, sale of bush products using donkey cart transport. It was noted that though land was communally owned under the trusteeship of the County Council of Ijara, it was mainly owned by males who also controlled grazing lands. Such land was acquired by inheritance or staking claim on the land that one wants. This largely implies that forest conservation strategies should target the socio-economic activities of men, probably through provision of alternatives and then reach out to the other gender for solid support.

Poultry keeping, livestock herding and honey selling are also major sources of income for the communities. Insecurity in the area denied the community market access and was a major contributory factor to enhanced poverty level and drives them to exploit the forest, a similar observation was made by Oppong & Oppong, (2004) in Kenya. This is also reported in Chonjo Magazine, (2012). The communities had not explored the potential of bee keeping and the few who engage in the business tend to do it at a very low scale. This was one of the activities that the study pointed out as a potential source of income and there is need to enhance its exploitation albeit using modern bee keeping technologies that reduce incidences of fire and the tendency to cut down whole trees thus destroying the ecosystem.

5.6 Agro-forestry as a conservation option

Agropastoral farming systems largely practiced in the study area would be improved through tree planting in the farms. It was observed that communities living more than 10 km from the forest had not adopted any agro-forestry technology and there are no existing strategies to meet their wood and fuel requirements. It was observed that at the time of the study, women walked for longer distances looking for firewood compared to 20 years ago. Rekha *et al*. (2008) argue that small-scale women farmers represent the majority of rural poor populations in developing countries. For greatest impact, agricultural development strategies must target these populations.Agro-forestry systems have provided numerous ecological and environmental advantages. They protect crops, livestock, soil and watercourses, stimulate biodiversity, contribute to carbon sequestration and even mitigate the effects of climate change. (Agroforestry in Quebec, 2006).

Use of agro-forestry as a conservation option can be addressed if agro-forestry opportunities are identified and the community empowered to drive implementation. It is needed urgently given the accelerated land degradation occasioned by overgrazing.

5.6.1 Clearing the forest for settlement

This was observed in Mangai and Bodhai where large chunks of forest have been cleared to facilitate settlement of both communitiesin villages inside the forest. The section where the Government deliberately settled the people and where the Ministry of Agriculture has introduced agricultural practices is threatened. This was further corroborated by observations during the transect walks and the visit to the villages.

Settling communities inside the forest has enhanced activities like selective logging which targets specific tree species and also results to opening of forests during felling, skidding and sawing and other non preferred species are destroyed together with the priority species. This generally leads to forest degradation. Laura (2003) largely asociated human activities to the approximated loss of global forests from the original 14% of the total land cover to less than 6% in the 21st century and stated that this causes ecosystem decay that results to a massive loss of plant and animal species and their roles. In some forests especially in the tropics, there is complete clearance of the forest resulting into large scale settlements. While the forests of Boni forest have not reached this stage, an influx of people into the area and a growth of the resident population may lead to such a scenario. Poverty is one of the factors leading to forest degradation and the influx of communities into Boni forest depicts such a scenario.

As the communities seek to be involved in forest management their poverty levels and their increasing developmental needs may influence their use of the forest. Peres (2000) explained that forest adjacent and forest dwelling communities often turn to the forest to meet their livelihood needs and this may compromise their role in forest conservation. The Boni and the Somali alter the forest inadvertently by helping disseminate certain seeds of wild plants (abandoned camps, gardens and villages providing particularly good examples of this), while anthropogenic secondary growth may constitute habitats for new kinds of plants and grazing animals. The Boni especially being hunter-gatherers change their habitat by dropping selected seeds which they collect for food.

5.6.2 Illegal logging

Illegal logging was also common in the closed forests as indicated by the presence of sawing pits, saw dust and tree stumps. It was noted that there was preference for specific species as identified from the stumps with the target species as *T.spinosa, B. huilensis* and *A. Quanzensis* leading to over-exploitation of these high grade timber species, confirming earlier observations by Githitho, (2004).

Some of these species were noted to have regeneration problems, which may affect their status in future. Although some species were identified as preferred timber species, the timber business was labelled as illegal by respondents and thus only done secretly without the knowledge of the government and was therefore not identified as a permanent source of livelihood. In some parts of the closed forests, no threats were observed and there was high percentage of litter cover. Communities indicated that about 10 species accounted for the total timber value of the forests with *T. spinosa* being the most widely used. This species was valued for its durable timber but had a limited ecological range which makes its exploitation probably non-sustainable in the area confirming findings by (Beentje, 1994). *P. africana, D.melanoxylon* and *A. quanzensis* were also cited as significant timber species. *R. mucronata* a mangrove species that was found on the intertidal zone of the coastal forests of southern Ijara was also listed as a significant source of timber (2% of the respondents), illustrating that forest products from the coastal region are accessed by local communities even in the far northern parts of the county. In the absence of an external market, most respondents stated that the amount of timber exploited for local consumption would be sustainable as removals from the forest would in essence remain low. However, if the timber was collected and sold outside Ijara area, then the forests were likely to be degraded with continued high removals.

Trees were noted as an important raw material in the building and construction industry in this largely rural set up. In making these non permanent structures, termite resistance was noted as a major aspect influencing preference. However, when the preferred species are no longer available, other species have taken up this role. Such species include *A. asterias, N. kaessneri, E. suaveolens, O somalensis, D. cinerea, N erlangeri, A dimidiata, E. capensis,* and *C. zimmermannii.*

The vegetation data indicated that the *Acacia* spp were relatively abundant and could stand a considerable amount of exploitation for charcoal use compared to *Dalbergia* and *Combretum*. In addition, *Dalbergia* is extremely rare nationally, and is under a Presidential Decree of protection. Its rarity is partially due to its high demand in the carving industry. Charles *et al.,* (2006) stated that conflicting developmental and conservation roles may result to forest degradation. Logging may to a certain extent also erode the value of the forest as a source of medicine especially if the health services are heavily subsidized by the Government. This may reduce the value placed on forests conservation efforts. The historical association of local communities with forest resources has played a great role in the conservation of community natural resources. This association with the forests commonly referred to as Indigenous knowledge systems (IKS) is fast getting eroded due to modernization. As such the forest resources are threatened because some modern conservation methods may not be compatible with forest community livelihoods.

Bray *et al.*,(2003) describes such knowledge and its implementation by the local community as a significant force in forest conservation and proposes the involvement of such communities in forest management at the local and national scales. This involvement is explained by Musila (2011) as an ideal method of forest conservation because the indigenous people have indepth knowledge of the forest. Involvement of the local communities in forest conservation and management in Kenya is captured in the Forest Act (GOK, 2005) where forest adjacent communities are advised to form community forest associations that will work as legal community entities in forest management. The associations registered under the Society's Act are expected to involve all forest user groups in the area and should be involved in the development of management plans for the forest to cater for the needs of the people while ensuring the sustainability of the resource. However, the operationalization of the Forest Act has not been achieved in many parts of the the country and communities do not have a clear idea of their role as defined in the Forest Act (Schreckenberg & Luttrell, 2009).

It was noted that there existed some traditional regulations that limit the use of certain forest products and this had made the forest sustainable. For example, the exploitation of common timber species was regulated and this agreed well with the provisions of the Forest Act (GOK, 2005) where communities have a big role in forest conservation. If such regulations are empowered by enforcement of conservation laws, then the forests may be conserved. Such regulations have resulted to the conservation of forests under the Maasai and Ogiek traditional regulations. They have also been described as the force behind the conservation of the Kaya forests by the Mijikenda community at the coastal region of Kenya (Robertson, 2002). However, like in the above cited cases, the future of IKS in forest conservation is hampered with little or no documentation, lack of clear procedures of passage of information and changing lifestyles. For example, formal education and conversion to conventional religions against the traditional lifestyles were listed as major impediments to the passage of IKS from generation to generation. The adoption of modern health systems may to a certain extent also erode the value of the forest as a source of medicine especially if the health services are heavily subsidized by the Government. This may threaten the intrinsic value placed on forests.The partial ban on plantation forest harvesting imposed in October 1999 has led to mixed reactions and numerous effects to the society and Kenyan economy in general. It is the common argument by foresters that the ban from harvesting gazetted forests is far from serving its intended purposes of protecting forests in Kenya. To the contrary, the ban has given rise to; lucrative black market for timber due to high prices thereby creating an incentive for illegal logging both in natural and plantation forests, loss of forest materials due to butt rots from edged plantations and windfalls, loss of jobs in timber enterprises due to the timber logging ban and decline in timber royalties from sale of trees to the forest sector. There has been expansive and uncontrolled exploitation of trees on private farms 5Km radius from Koibatek forest zone, poor performance of plantations at maturity i.e pole sized industrial plantations due to lack of thinning and/or pruning at different growth stages as required. Latest statistics indicate that the country spends more than Ksh 3 billion ($37.5 million) annually on timber imports compared with Ksh 4.9 million ($61,250) in 1999, to meet rising demand that now stands at 38 cm^3 million annually. Industry players blame the huge cost gap to the increased timber prices which increased from Ksh8, 000 ($100) in 1999 to more than Ksh30, 000 ($375) per m^3 in 2012 of sawn wood timber. Moreover the cost of forest policing and enforcement has gone high depriving forest sector other fundamental activities like thinning, pruning, protection and plantation establishment.

Common Uses of the woody species in the three forest ecosystems Arabuko Sokoke, Shimba Hills and Tana flood plain forestscompares quite well with the results obtained for Boni forestwhich include: Fuel wood**-** *A. quanzensis* (Mbambakofi), *H. verrucosa* (Mtandarusi); Fruits-*A. petersiana* (Matongazi); Wood-Carving-*C.webberi* (Mfunda); Timber (Illegally obtained); Poles- *C. schumann* (Mgurure), Medicinal plants (Lukando, 1991 identified 80 medicinal plants used here) (MENR, 2002).

The findings from the study complement what is happening in the East African Coast ecosystems, - environmental degradation continues uninhibited. Destruction of woodland and mangroves, slash-and-burn agriculture, illegal hunting of wildlife and unregulated off-shore trawling are all diminishing the regions' resources. The escalating loss of biodiversity in these areas is accelerated by combined effects of the burgeoning human population, growing poverty, limited chances of employment among the young and energetic population, the soaring demand for food, inadequate stakeholder involvement, conflicts of interest and corruption, among many others. The biological and social-economic importance of Boni forestis enormous just like that of Arabuko-Sokoke, Tana and Shimba Hills Forests. Building focus on the woody species of the forest is paramount since the existence of other flora and fauna species (including humans) in the ecosystem largely depend on them to enhance their survival. In addition, any woody species take much longer time to establish than almost every other plant species.

5.6.3 Grazing

Ideally the Somali community is mainly pastoralist but due to declining incomes from livestock, most households have embraced farming. The community is sedentary with both short and long range grazing systems, mainly in the forest. This has also been documented by Githitho, 2004. The animals kept are mainly cattle and goats. Long range grazing involved moving with the whole herd of animals into the southern end of Boni forest near Witu in Lamu District and short range involved grazing sick and a few milk animals near the manyattas.

The study noted that livestock from the rest of the district and county were grazed within the forest which was considered a dry season grazing refuge (Kenya Forest Working Group, 2011). More often the animals were grazed in the section of the forest in Lamu District during drought where there was plenty of pasture and no tsetse fly threat. The main constraint to livestock keeping was tsetse fly (*Glossina morsitans*) menace; (Matiku, 2002). The elders ensured that sections of the forest with high tsetse fly infestation were avoided. The presence of the tsetse fly in certain sections of the forest had to a large measure been a deterrent to invasion of the forest by would be loggers and rampant grazing.

Notably, these livelihood strategies seem to be changing with changing developmental needs and land use activities. Findings showed that livestock keeping was the most common livelihood strategy 20 years ago (Kenya Forest Working Group, 2011) but it had been declining mainly due to reduced pasture, livestock diseases and insecurity. This implied that the potential for many youth to turn to logging was quite high. Livelihood strategies that have been gaining acceptance and may become dominant in the community in the years to come include sheep and goat rearing, transport, crop farming, honey harvesting and poultry farming. All these activities were either non-existent or of little importance 20 years ago but seem to be coming up at a great scale as corroborated by Githitho, 2004. The preferred livelihood strategies will obviously influence the relationship between the communities and the forest. For example increased crop farming implies clearance of the forests for farmland. Such forests may be perceived as idle lands that should be exploited by clearing them and planting crops. The increase in the number of goats may also interfere with regeneration activities in the forest because these browser animals feed on the young trees and seedlings, and may therefore not allow them to grow to maturity/productive stages for regeneration.

Urbanization and changing livelihoods was evident mainly from the presence of kiosks, shops and businesses which were said to be non-existent 20 years ago during transect walks and observation studies. This has also been affirmed by the Kenya Forest Working Group, 2011. Such businesses are likely to continue to thrive as the population grows. The desire for more money to spend under such changing lifestyle may unwittingly lead to further decimation of the forest.

5.6.4 Forest fires

Fires were noted as a major threat to the forest specifically in the southern part of the county. The Government's program of resettlement of communities in the forest has led to the increase of slash and burn agricultural methods thus increasing reasons for starting fires. This is increasingly a result of inadequate land-use planning and land tenure system, as the government in an effort to meet the demands of local communities in search of settlement did not give adequate consideration to the impact of such actions on forest management. Threats from fire were found to impact heavily on the following species: *D. melanoxylon, A. quanzensis, N. hildebrandtii, S. africana, T. spinosa, T. prunioides* and *A. drepanolobium.* These are trees highly vulnerable to fires due to their ease of combustion (Orwa *et al*., 2009). Farmers caused uncontrolled fires that spread to adjacent areas outside their swidden (slash and burn agriculture) resulting in wildfires. During the field work, evidence of such fires was through the observations of large open areas, scars on trees and was confirmed by the communities (during interviews and discussions) as a major threat to the forest.

Fires of both natural and anthropogenic origin have known biotic and abiotic effects on ecosystem properties and the environment. The biotic effects of fire include changes in vegetation and subsequent impacts on wildlife. Abiotic effects include changes in soil properties, nutrient cycling, water quality, and air quality. The quality of life experienced by human populations is also impacted.

Vegetation fires have become a common event in tropical ecosystems in the past two decades (Mueller-Dumbois, 2001; CBD, 2001, Dennis *et al*, 2001; Nepstad *et al*, 1999). Other tree species tend to occupy repeatedly burned areas thus altering the species composition and diversity of a forest. Through time, it becomes more difficult to utilize the land for agricultural purposes and the area will in the long run remain degraded and unproductive. Additionally, through the continued activities of timber harvesting, forest conversion into monoculture and agricultural plantations, illegal logging, or slash and burn agriculture, health of the forest / ecosystem will continue to decline and be degraded within the next decade. This will result in the loss of ecological, social and economical support, all critical functions that currently benefit the local community, an observation made by (Ochola *et al*., 2010). In the southern part of Ijara Sub County where the forest is more intact, anthropogenic fires were common. The fires were associated with slash and burn farming methods as well as wild fires from hunters and honey gatherers. Forest fires were most severe in Mangai area while wildlife damage was most severe in Mararani and Sankuri locations.

5. 7 Threats on Forest Environment

In the study area, activities that never existed traditionally are now being adopted including timber sawing, goat grazing, farming and honey harvesting. These activities were associated with activities that tend to diversify household production forest. This is what Tania *et al.* (2003) and Charles *et al*., (2006) referred to as compromising developmental and conservation roles which in many cases result to forest degradation.

The study established that there was a statistically significant difference (Kruskal-Wallis H (2) =7.040, P=0.071), between the threats on environmental subcomponents as indicated by farmers' perceptions. The mean ranks were 12.75, 15.80 and 21.85 for soil component, grass layer, and herb layer respectively and the mean for the overall vegetation cover was 23.50. There also exists a statistically significant difference between the threats in the forest (H (2) = 3.278, P = 0.051). Mean ranks of 7.50, 20.75, 19.89, 22.50 and 12.43 were recorded for forest fires, grazing/browsing, cultivation, settlements and pole cutting. However threats on the forest due to wood carving, honey harvesting and over grazing were lowly rated by communities.Among the Boni, there was a sense of loss of ownership of the forest resulting in a lack of respect for forest protection among a cross section of the society. This is brought on mainly from the introduction of new ways to enhance food security such as agricultural practices by the government.

Damage by wildlife, especially elephants, had led to a lot of tree felling which was particularly conspicuous in Sankuri which as indicated in forest height dominance could have led to removal of the emergents in some areas. The population of wild grazers such as buffaloes, as indicated by dung content was high in Transect 4 and this explains the depletion of the pastures within the reserve.

Threats to the forest identified in the study had significant effects quite similar to many forests in Kenya (Baldyga, *et al*., 2007; Hitimana *et al*, 2004 and Kinyanjui 2011). These are threats associated to forest clearance, forest fires, cultivation and excessive exploitation of commercial species. Such activities have been cited as the greatest forces influencing forest depletion and degradation in Kenya (GOK, 2005) and in the world (Laura, 2003) and as such mitigation activities to forest degradation should be implemented to protect remnant forests as indicated by (Trapnell, 1959). These findings corroborate findings of WWF (2012) and other studies that the coastal forests of Kenya are facing threats due to unsustainable exploitation specifically targeting commercial timber species. In the case of Boni forest where an influx of subsistence communities of people into the area and a growth of the resident population posed a great threat to the forest through clearance for agriculture, the forest may be described as fragile and requiring immediate action in terms of conservation measures.

The pristine conditions of the forests isassociated with indigenous conservation methods which protected the whole forest or some individual tree species. This knowledge improves the ability of communities to balance the array of demands on natural systems while maintaining ecosystem productivity and integrity. Important to note is the fact that several important ecosystem processes circulate, transform, and accumulate energy and matter. These processes include biogeochemical cycling, primary productivity, respiration, food-web interactions, and succession. At the heart of these ecological processes are individual species that serve to purify water, build soils, and recycle nutrients. Natural disturbances continuously disrupt these ecosystem processes and maintain most systems in a constant state of biotic and environmental change.

A Krusal Wallis Test based on ranks of threats (on a five pointer Likert scale) showed that the size of threats was similar among study locations but only the activity differed from one place to another. This was attributed to the fact that the 80 sampling points in each transect gave a variety of values that clearly compared on average. The northern side of the study area which was drier had more tree cutting for construction and firewood purposes. There was also overgrazing that led to soil erosion. Communities in the northern side of the study area maintain large herds of cattle, sheep, camels and donkeys (a combination of grazers and browsers) which easily depleted the pasture that was available leaving the soils bare and loose due to trampling. The study noted that soil erosion was an important threat. The findings of the study indicated that environmental impacts of forest degradation may lead to reduced plant biomass, reduced biological diversity, loss of valuable species of economic/ethnobotanical value, reduced ecosystem services and stability, disturbed habitats, broken food chains and species extinction, this concurs with findings made by Ash (2010). Threats to the forest identified in the study were moderate compared to other forests of Kenya as was examined by (GoK, 2005) and the vegetation health was strongly influenced by climatic seasons rather than anthropogenic factors. The ability of the vegetation to recover after a low season indicates that the health of Boni Forest vegetation is more influenced by the seasonal variations of climate rather than effects of human influence. The low and high seasons corresponded well to the rainfall patterns of the area (ALRMP, 2005).

The study found out that there is no common vision and approach to conservation initiatives among the managing institutions. Though the national and forest reserves are administered under different authorities, they fall within a common landscape which means that they should be managed from one authority. This was the case with some part of Boni forest being managed under Pwani conservancy of KFS while the northern part was managed under the Ewaso Conservancy. Due to this confusion, although the areas of Boni and Dodori national reserves are generally known, various authorities give different figures in terms of their areas. Community Forest Associations (CFAs) which are clearly indicated in the Forest Act, (2005) should be formed where communities are expected to work together with the government in conserving the forest while sustainably tapping the benefits. CFAs in other forests especially in Central Kenya have signed forest management agreements with KFS after developing participatory forest management plans.

The Kenya Forest Service (KFS) has an interest in gazetting both Boni and Lunghi forest reserves. Whereas the national reserves enjoy better protection from Kenya Wildlife Service (KWS), the two adjacent forest reserves, under the county councils of Lamu and Ijara Sub Counties, are less protected and endure the brunt of deforestation, degradation and mismanagement generally accorded coastal forests of Kenya. Despite the biodiversity richness of these forests, there is little incentive and responsibility for their conservation, a situation made worse by the general insecurity of the area.

An integrated ecosystem based management plan is needed to guide activities and to ensure they are consistent with an overall vision for the Boni Forest ecosystem, stakeholder interests, roles and responsibilities, community livelihoods, extractive industries (logging for timber, wood carvings and furniture), ecosystem functions and values, management infrastructure (roads, outposts, forest stations, watch towers, etc), management frameworks, available and projected resources (transport, fire fighting equipment, etc), law enforcement mechanisms, opportunities, threats and the means to combat them. The fundamental role of the integrated ecosystem based management plan will be helping to limit additional Boni forest degradation that threatens the continued provision of environmental services, livelihoods and economic well-being while at the same time promoting the conservation of the highly diverse biological resources found in Boni forest.

The integrated ecosystem based management plan should give room for synergizing Indigenous and the Scientific Knowledge Systems. In so doing, this paper suggests that the indigenous and the scientific knowledge systems are synergetic and do complement each other on their strengths and weaknesses, and their integration might achieve what cannot be achieved by either in their separations.

Occurrence of droughts in the ecosystem and the challenges they cause especially those associated with the forest being a dry season grazing refuge pose a threat. Climatic changes and severe weather conditions have great potential to cause devastation of the

Boni Forest and can become a major driving force behind wildfire, insect and disease outbreaks because frequent floods and droughts have enormous potential to devastate and cause changes on ecosystem conditions. The community was found to be poor and marginalized with very low resilience to climate change.

5.8 Forest Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) data was used to assess change in forest vegetation for the period 1999 – 2011. The NDVI shows the state of vegetation health and density (Eastman, 2001) of the woody vegetation of Boni forest as shown in Figure 4.6. From the NDVI data, the vegetation health and density was seen to be strongly influenced by the seasonal climatic variations within a year. The highest values of NDVI recorded when the vegetation was very healthy (green) indicates that the vegetation of Boni forest is good.4 Similarly, the lowest status of the vegetation recorded in the dry season was 0.4 which shows that there was no big variation between the high season and the low season and the low vegetation health could have resulted to the deciduous nature of some trees. The ANOVA test indicated no significant difference ($P< 0.05$) in the NDVI values for the years 1999, 2005 and 2011. The ability of the vegetation to recover after a low season indicates that the health of Boni forest vegetation was more influenced by the seasonal variations of climate rather than effects of human influence. Despite this finding, the NDVI values for the closed woody forest indicated inferior vegetation compared to montane forests like South West Mau and Transmara forest (Kinyanjui, 2011) where the NDVI values are slightly higher either due to higher closure of the canopy or due to better health of the vegetation. The values of vegetation health and density for this forest were only similar to those of Eastern Mau forest which Kinyanjui (2011) and Baldyga (2007) described as degraded due to fires and human encroachment.

5.8.1 Community livelihoods and use of the forests

The Somali and Boni communities as shown by the study findings were ready to intensify farming and introduce new crops such as millet and sorghum to enhance food security. This implied further clearance of the forest, more occurrences of fires as they are used to prepare land for farming and generally more destruction of the forest. This situation would be made worse by the current conflicting policies on land use and conservation with the ministry in charge of agriculture favouring expansion of farming areas and the Kenya vision 2030 (GOK, 2007) favouring the opening up of remote areas through intensification of road and railway systems some of which are expected to pass through this forest.

Drivers of forest degradation that affect biodiversity indirectly also affect bio-diversity-dependent ecosystem processes and services. Among these change drivers, a major threat to biodiversity-dependent human well-being is large-scale land use change, especially the intensification and extensification associated with large-scale industrial agriculture. This threat is most obvious for those human groups that are already vulnerable because their livelihoods rely strongly on the use of natural and semi natural ecosystems. These include subsistence farmers, the rural poor, and traditional societies (Sandra *et al*., 2004).

It was realized that the forest community was similar to the Ogiek forest dwelling community of the Mau Forest whose coexistence with the forest has been sustainable until their population exploded and they adopted modern farming methods which have caused destruction to the forest similar to what was realized by (Ochola *et al*., 2010). This is often the case with forest communities who start with good conservation methods when their socio economic set ups are harmonius and was similary observed by (Vogt, 2007), but the case oftenly changes when there is an influx of foreign communities who have no traditional linkage with the forest resource and who often see the forest as an idle resource that can be exploited for developmental needs. This was also confirmed by(Schreckenberg and Luttrell, 2009).

5.8.2 Tree and shrub species exploitation

Regardless of high plant diversity in Boni Forest, valuable timber tree species had been harvested illegally. This was evident in the number of coppices observed from the stumps, indicating that stems were cut. Presence of pits and wooden platform for sawing in the forest also points at illegal harvesting of the mentioned tree species. Rampant harvesting of timber species has been reported by (Poore, 2003). This is also confirmed by reports from KFS who reported that illegal and selective logging of valuable species such as *A. quanzensis*, *D. melanoxylon* and *T. spinosa* contribute to over exploitation of these tree species. Over exploitation of these species in similar ecosystems and resultant forest destruction is also reported by Waters *et al*., (2006). Furthermore, the presence of cut stumps and old earth kilns in the forest revealed that charcoal making is a crucial activity in the study area. Species frequently used for charcoal were *C. molle*, *Brachystegia* and *Julbernadia* species.

The study established that both the Somali and the Boni communities depend on Boni Forest and its divergent ecosystems and therefore have potential to decimate or protect the ecosystem. This is largely affirmed by evidences gathered by Githitho, (2004), when he studied the coastal territorial forests of Kenya to establish resource threats and investment opportunities. The study also noted that both communites have great skills that enable them to identify, assess, and undertake practical actions that can enhance the well-being of the Forest without undermining ecosystems. The study noted that these communities have influenced and are influenced by ecosystems through multiple interacting pathways and that no action in the ecosystem is too small to be ignored. Current anthropogenic threats may lead to detrimental (and perhaps irreversible) ecosystem degradation, providing strong motivation to evaluate the response of ecological communities to various anthropogenic pressures (Sardinha-Pinto, 2008). Increasingly there is evidence that serves to highlight the dangerous possibility that loss of biodiversity may result in a decline or loss of crucial ecosystem services (Duffy, 2009; Cardinale *et al*., 2012; Hooper *et al*., 2012). The safeguarding of biodiversity is of the highest priority if human well-being is to be sustained in the face of global change (Díaz *et al*., 2006; Loreau *et al*., 2006). Current species loss in Boni Forest is not random and could potentially result in critical loss of vital ecosystem functionality, a fact similarly examined by Zavaleta & Hulbey, (2004); Bracken *et al*., (2008); and Selmants *et al*., (2012) in their work in other ecosystems. For example, human activity can threaten the diversity of natural avian communities, affecting ecologically and economically important functions such as seed dispersal, seed predation, pollination, and pest control (Tscharntke *et al*., 2008; Karp *et al*., 2011).

5.9 Community Perceptions on Threats to the Forest Resources

Significant threats to the forests were identified including deforestation, forest fragmentation and settlements (increased numbers of structures/houses). Conversion of forest land into agricultural landscapes was also cited as a significant environmental threat. In Mararani, communities indicated wildlife and poor enforcement of laws as threats to the forest. In all the other study areas, respondents indicated that forests were degraded due to local factors among the community. Such factors as slash and burn, settlement and illegal logging were all ascribed to the communities. This was an indication that communities knew the source of problems to their forest resource which is important in developing forest rehabilitation programmes.

In the case of logging activities, as noted earlier, there is over-exploitation of a few selected high grade timber species such as *T. spinosa* and *A. quasensis* (Cunningham *et al.*, 2005). For these species, it has proved to be very difficult to regenerate, making their future very uncertain and threatened. One of the major markets identified during the study was from a Canadian of Somali origin. Most valuable indigenous timber tree species are selectively harvested, aimed at removing the best mature trees leaving unsalable and defective trees. Some of the indigenous tree species are now in danger of genetic impoverishment while others are threatened with extinction (Kenya Forest Working Group, 2011). The study noted the quick response from KFS to apprehend culprits and save the threatened species.

5.10 Illegal Plant Resource Collection

A determination of the threats to the forest resource was done by considering the number and kind of offences that were reported by KFS in their occurrence book. The offences that occurred between 2005 and 2010 were dominated by illegal logging. The most commonly logged species were *T. spinosa* and *A. quanzensis*. From the interviews it was reported that those who committed the offences were rich people with proper logging and transport facilities and therefore caused large scale deforestation. It was also noted that at times the logs cross over national borders into Somali.

The clearance of indigenous vegetation disrupts ecosystems and habitats and results in the creation of remnant 'islands' or fragmented patches (Sardinha-Pinto, 2008). Few of these remnants are large enough to sustain ecological processes such as water and nutrient cycling at the rates that existed before disruption, a similar observation was made byGithitho, (2004). Many of the destroyed ecosystems continue to be disturbed by threatening processes such as invasion by weeds or feral animals coming from the surrounding cleared land.

Habitat fragmentation has two primary effects. First, it creates new edges between remnants and cleared or disturbed land leading to 'edge' effects (Sardinha-Pinto, 2008).

These include physical changes to the remnant in the border region, such as different levels of exposure to the sun and wind and changes in water cycles and the local air temperature (Lindenmayer & Fischer, 2006). Biotic changes include invasion by opportunistic species with good dispersal or colonising abilities such as weeds and feral animals. Second, it isolates and creates barriers between remnants. In most cases, recently isolated remnants can be expected to continue losing species (Huettmann & Cushman, 2009). For some species the loss of a population of a species made too small to be viable may take considerable time due to the relatively long life of individuals. For example, it may take several hundred years to lose some species such as long living trees, particularly since adult plants are often less sensitive to changed environmental conditions than plants in seedling and juvenile stages. This phenomenon also applies to fauna including some invertebrates such as individuals of a species of trapdoor spider in the wheat belt of Western Australia which may live for at least 23 years (Main, 1987). The consequences of habitat fragmentation on biodiversity depend on the interaction of these effects and influence (Sardinha-Pinto, 2008) and almost certainly vary for different species and habitats (Van, 2008).

Land clearances and erosion arising from farming, agriculture, industrialization and urbanization have led to an enormous loss of indigenous customary knowledge and practices relevant to biodiversity. These, combined with a loss on biodiversity and changes in growing patterns and habitats of flora and fauna, means it is difficult for indigenous people to demonstrate their exclusive rights to biological species, and knowledge of these. The number and variety of threats to biodiversity are important to know for identifying and applying an appropriate suite of conservation activities to an eco-region, but it is the cumulative impact of all threats that is of paramount importance for assessing trends in the viability and diversity of biological systems (Huettmann & Cushman, 2009). The approach proposed here views change from the perspective of impacts on multiple levels of biodiversity, rather than an inventory of human mechanisms of change. According to the international environmental conservation organisation, the World Wildlife Fund (WWF), ongoing encroachment on forest mountain ranges threatens the existence of rare plant and animal species (WWF 2012).

5.11 Indigenous knowledge systems and Forest Conservation

5.11.1 Community livelihoods

The Boni also refered to as the Awer are hunters and gatherers who live in Boni and Dodori Forest Reserves at the southern border of Kenya and Somalia, from where they draw their livelihoods. The Somali are mainly pastoralists. Arid and marginal climatic conditions in the area inhibited the Awer from farming. Consequently, the community depended on a diversity of plant species from the forest for medicine, food, building and construction, timber, domestic tools, honey harvesting tools and even for religious purposes. Over time they formed a body of knowledge in each of these areas that has helped them survive the harsh environment and in the same breadth conserve the Boni forest and its environs.

5.11.2 The pastoralist community grazing zones

Communities of Ijara Sub County have a rich knowledge of their forests and a clear idea of how to conserve the forests. They have a wide range of uses of the forest which naturally spurs them to conserve the forest. The Boni and the Somali communities also useIndigenous knowledge systems (IKS) to preserve the environment and generate goods and services on a sustainable basis; similarly this was confirmed by (Matiku, 2002, Fernández 1994). IKS has had a profound effect on the preservation and conservation of the natural species in Boni forest for many generations. During drought, crop failure, famine, floods or any other disaster, communities turn to their indigenous knowlegde to determine the way forward. Ideally the Somali community is mainly pastoralist but due to declining incomes from livestock, most households had embraced farming. The members of the community had specific land set aside for grazing. The Somali alternated the use of grazing land according to seasons.This required a timing decision on when and where to move next based on a well established indigenous knowledge system driven by experienced elders.

5.11.3IKS for seed propagation

The communities had indigenous knowledge system on seed propagation which ensured continuity of certain plant species. They knew which species had regenerational problems and how to propagate them having acquired such profound knowledge from years of trial and error, an observation made byGithitho, (2004). Local people were aware of the extent of variation as well as the traits displayed by genetically superior individual trees or intraspecific taxa. This knowledge of tree-to-tree variation and consumption uses is valuable in research and development. They had knowledge on plant physiology, understanding of their reproductive biology, as well as knowledge on species that thrived in the dry season and those that provided dry season pasture and food.

The communities had knowledge on the role of other organisms in the dispersal of seeds of specific trees. For instance birds dispersed leguminous plants which bore seeds in pods and these were largely members of the family Mimosaceae. They also knew the value that trees served to other non-human organisms as food. For example, specific trees that flowered at specific seasons were a source of nectar for bees and it was possible to determine the trees that had provided honey at specific times of the year. The study noted deliberate preservation of corridors of mature forests between plots as some kind of biological reserve to provide habitat and food for animals which were of importance to the community especially in seed propagation. Noted also was the special way the Boni extract, protect and ensure future supplies of plant resources, much in the same way described by (Sardinha-Pinto,2008). The Boni had vast knowledge about plants and animals that could contribute much to current scientific work. They had important knowledge on propagation of seeds to ensure continuity of certain plant species. Such species were usually of significance during droughts as they are used for food. They therefore had profound knowledge on their physiology, understanding their reproductive biology, of what parts are useful and how to process them, of the damage they could do to humans and other organisms upon which humans were dependent (toxic yams, insect pests, dangerous snakes and so on), the role of other organisms in the dispersal of seeds and the use made of the species by other non-human organisms as food.

5.11.4 IKS for grazing purposes

The indigenous system of pasture management has complex features reflecting the inter-relationships between human adaptations, environmental variability, systems of land use and local decision-making systems (Little, 2003). The Somali communities rely entirely on their own experiences and knowledge, which they have used for generations to manage the grazing zones. Their indigenous knowledge system has never faded since it has been in use for several decades and is used in their daily encounters, a fact also observed by (Grice &Hodgkinson, 2002). This is useful to them in maintaining a healthy stock and in ensuring that their herds of livestock access quality pasture and water. They undertake assessments of grazing zones using ecological and anthropogenic indicators. They use soils, vegetation and livestock production as the main indicators of pasture condition. In addition, the pastoralists use key-plant species to assess landscape-grazing suitability and soils to assess landscape-grazing potential. The latter is critical for evaluating potential stocking densities that each landscape could support during the wet or dry grazing seasons. For anthropogenic indicators herders use milk yield, body hair condition, weight gain and mating frequency to assess livestock production performances. Pastoralist scouts assess pasture degradation and trends using historical knowledge of the landscapes (Oba, 2012). Among the Maasai community of East Africa, they have the following flora (each species with Maasai name in bracket) as some of their indicator species; *S. incunam*(Endulelei) *D. diagonalis* (Asangari), *A. longiscupes* (Olokororom), *H. aponeurus* (Engaranyi), *J. euosmia* (Oloiyet), *O. africana* (Olorien), *J. procera* (Altarakwai), *L. javanica* (Osinoni), among many others (Mapinduzi *et al*., 2003). This system of indigenous pasture assessments and monitoring could rapidly provide information needed by policy makers to plan for any sound conservation and forest management activities in pastoral areas. Harnessing pastoralists' indigenous pasture management knowledge has implications for participatory research, for verifying and testing methods, as well as for sharing information in order to promote practical rangeland management and biodiversity conservation. Most of the East African rangelands (grasslands, savannas, shrublands, and woodlands) are inhabited by multi-ethnic pastoralist communities who keep livestock (cattle, camels and small ruminants) as their main source of livelihood.

5.11.5 IKS for medicinal purposes

The study identified indigenous knowledge system for medicinal purposes like treating snake bites, livestock diseases and control of insect pests. The communities had plants that they ate during the drought period and that were said to sustain them for long periods. The art of native medicine has been practiced in East Africa for many years, and is still even being practiced today. The knowledge of medicinal plants is normally passed on orally from generation to the next. The part of the plant used varies from species to species, and also depends on the structure of the plant. For trees and shrubs the common practice is to use the bark or roots or sometimes both. Less commonly used in this group are the leaves while flowers or fruits (including seeds) are rarely used (Kokwaro, 1976). There is a huge contribution of ethno-botanical information in drug discovery that has been greatly acknowledged by scientists (Balick *et al.*, 2000; King, 1994). Many studies amply prove that search for new drug (or lead for it) is far more successful when it is based on the clue related to their use by local people. Drug-searching pharmaceutical firms such as Monsanto make use of indigenous knowledge system about the medicinal feature of the plants or biota in general. In order to use the local information in the search process, the firm approaches the locals directly. They then collect plants for assaying and screening after discussions with the indigenous healers and observing them work. They have employed a plant targeting strategy where they choose a plant for testing as and when they find that two or more communities use the same plant for medicinal purposes. The success rate of drug discovery after following this rule of thumb has been more than 50% (Kumar, 2004). In such cases, locals can claim for a higher royalty linked to the net sales revenue from discovered successful drugs. Prevailing practices also confirm this argument. It is reported that crude extracts of plants used by a healer in Belize (Brazil) produces four times as many positive results in lab tests for anti-HIV activity than did specimens collected randomly (Balick & Cox, 1994). If a search for useful drugs is led by the knowledge of indigenous people who know possibly more about the characteristics of these plants, the probability of getting a ‘hit’ will considerably improve and consequently reduce the overexploitation of plants and plant materials in the bio-prospecting process. This will greatly contribute to biodiversity conservation in a win-win situation where the locals can benefit from the sharing of the benefits resulting from the bio-prospecting while the pharmaceutical firms benefit by incurring less cost in the process.

5.11.6 Use of the tree species based on IKS

The study found out that *S. persica* could be made into tooth brushes. Chewing of sticks of *S. persica* was a habit in most of the study area in both rural and urban centers. These sticks were normally chewed for purposes of cleaning teeth as an alternative to tooth brushes and tooth pastes. Studies elsewhere indicate that the traditional toothbrush is just as effective as the modern tooth brush (Jamal *et al.*, 2011). It was even claimed that the local communities did not have dental problems due to the chemical composition of the chewing sticks. There is need to document the extent of the use of traditional chewing sticks as toothbrushes and their effectiveness and also the preservation of plants producing the toothbrushes. The Boni were well-informed on many species not because they were directly of use to humans but because they represented the food of animals which they hunted, particularly. In other words, as noted by Ellen (2007), plants and animals had to be understood as part of the web of forest life, not simply in isolation. Thus, it was adaptively more important to distinguish varieties of yam from one another because one contained toxic levels of dioscorine and the other was edible, than to distinguish them on the basis of perceptual criteria alone (say size of leaf), though such features may indeed flag crucial functional distinctions (Maass, 2008). This kind of knowledge is the result of generations of accumulated experience, experimentation and information exchange (Van, 2008; Sardinha-Pinto, 2008).

5.11.7Use of trees for fuelwood and charcoal prodution

Most plant species were noted as good sources of firewood, except some species such as *Croton sp* that are avoided for some reasons such as its strong pungent smell, a fact also recorded by Rai *et al*.,(2012). It should be noted that *C. pseudopulchellus* a member of the Croton family was one of the most abundant species as indicated in the vegetation surveys and this could be associated to its seldom utilization. *C. nilotica,* a tree of the coffee family whose relative abundance was high, was mentioned as a good firewood species at all the sites due to its non-smoky wood, ease of availability and optimal heating characteristics (Pakia, 2005).

Despite the generality of fire wood usage there were preferred species for this use. These included *D. melanoxylon, C. schumannii,* and *C. suahiliensis*. The community indicated a decline in the firewood availability (40% of the respondents) and cited species like *B. huilensis*, and *D. melanoxylon* as some of the trees whose availability has considerably reduced. Observation surveys confirmed the availability of fuel wood in the various compounds which was kept in large stacks in virtually all the homesteads, attesting to the fact that firewood is readily available in the Forest. They however qualified that this is fetched from right inside the forest unlike in earlier times when they would get it from very short distances in the periphery of the forests.

For charcoal production the species preferred were mostly from the Acacia family such as *A. seyal, A.bussei* and *A. nilotica* (Pakia, 2005). Due to the uneven distribution of these species as indicated by the species dominance results the two communities indicated different preferences for these species. The Boni had higher preference for *A. seyal* while the Somali preferred *A. nilotica*. These species were found within easy reach of the homesteads, mainly in the grasslands. The reason for the preferences lay mainly in the fact that the Boni being hunter gatherers preferred the *A. seyal* because they use the stems to make shafts for their spears while the wood isused for a variety of things, they ate the gum produced by the tree, and the leaves were also used for fuel (Cunningham *et al*., 2005). The Boni also relied on it because of the tannin in the bark, which is used to treat dysentery and a number of other illnesses. The gum produced was used to treat chronic diarrhea, colds, and even hemorrhaging. The wood of this tree was used to reduce fever, as well as treat pain associated with arthritis.

The vegetation data indicated that *Acacia spp* were relatively abundant and could stand a considerable amount of exploitation for charcoal use compared to *Dalbergia* and *Combretum*. In addition, *Dalbergia* was extremely rare nationally, and is under a Presidential Decree of protection. Its rarity is partially due to its high demand in the carving industry (Huxley *et al*., 2005).

5.11.8 IKS for predicting weather

The Boni and Somali predicted droughts by observing the behavior of certain bird species and listening to the piercing cries deductively. They believed that since birds travel far and wide, they are able to bring them news of impending disasters. They could also foretell disasters as well as weather related diseases by watching the movements of celestial bodies in combination with observing the date of emergence of certain plant species. These early warning signals of an approaching environmental disaster were used to determine any preventive measures, prepare for mitigation and decide on the course the community should take in using the natural resources. Concerning animals, they studied the positioning of animal intestines when slaughtered and could predict droughts. Similarly, estimates of animal fertility could be drawn from such forecasts with implication on stocking rates and density (Orwa *et al*., 2009). This knowledge has been little researched on so far.

5.11.9 Indigenous knowledge systems for forest conservation and water harvesting

The Somali had indigenous knowledge system which they used to accurately position water pans. A number of incidents were narrated where such advice was ignored by development workers to their own peril.Such knowledge came with years of experimenting and accumulating practical knowledgea fact cited in Monroe & Ogundiran, (2012) who have over the years worked among indigenous peoples. It also had to do with knowledge of certain species of plants with high affinity for water such as the palms and bamboos, thus reflecting proximity of the water table. Traditional water harvesting structures were also habitats for a variety of species. In view of accelerating biological and cultural landscape degradation, a better understanding of interactions between landscapes and the cultural forces driving them is essential for their sustainable management.

5.11.10 Indigenous knowledge systemand livestock pests and disease control

The study observed that livestock production was a source of employment and livelihood among the Somali.It involved the rearing and marketing of livestock comprising cattle, sheep, goats and camels. The study also noted that livestock keeping was a male dominated occupation. The Somali practiced mobile pastoralism or transhumance which involves movement of the herdsmen, their families, and the herds from place to place, with the availability of fodder, water and animal health as determining factors(Roe*et al.,*2009). In recent times however, the families tend to settle in one place while the herdsmen move from place to place. The impact of the livestock on the forest is great, leading to forest degradation especially during drought years. The cumulative impact of grazing and trampling also had an impact on the forest. A number of forest fires were attributed to herders albeit from outside the Sub County.

Much as cattle are kept as status symbol, hard times aggravated by frequent droughts force the pastoralists to enter hitherto uncharted areas such as beef production, hides and skins and milk production as well as for traction power on the recently acquired farms. Support for these initiatives was largely from Government projects and NGO driven projects. The forest provided a source of medicine for their livestock in order to cure different ailments. The greatest threat faced by livestock trade was from the tsetse fly (*Glossina morsitans*) followed by ticks (Ixodid ticks). Common livestock diseases such as diarrhoea, rinderpest, anthrax, foot and mouth disease and East Coast Fever were noted. Pests and diseases were two of the greatest threats to the realization of the productive potential of livestock as a means of livelihood. The study noted that pests and disease control was undertaken by combining both indigenous knowledge system and veterinary knowledge obtained from vendors at the few trading centres. However, indigenous knowledge system formed the backbone for ensuring healthy herds mainly because the rural poor lacked the means to access agricultural extension and supportive delivery systems and services wherever available. In such a situation, the farmer was largely dependent on traditional practices of pest management based on empirical experience as advanced by Gordon & Krech (2012). 10-11% of the respondents said they used concoctions from either plant or animal parts to control pests and diseases, while over 42% said they used slash/burning to control pests and diseases. A similar percentage said they combine both traditional medicine and slash/burning to control pests and diseases.

5.12 Forest Land Tenure

The study observed the unclear circumstances in which the Boni and some of the Somali lived with the entire Boni tribe living within the forest in new settlements organized by the Government. From the outset it was known that land ownership was a problem. The State was the legal owner of communal land including the forest. A fundamental goal in these very unclear circumstances was to enhance and to secure people’s land rights. This may be necessary to avoid arbitrary evictions and landlessness. It may also be essential if rights holders were to invest in the land and to use it sustainably. It was observed that insufficient attention has been devoted to post-settlement planning and support. This meant that the livelihoods and the land rights of forest settlers have too often remained insecure. For those relying largely on local rural resources for their livelihood, a secure place to live, free from threat of eviction, with access to productive land and natural resources are essential for rural livelihoods in the region.

Settling the Boni and Somali in the forest tended to underestimate the importance of indigenous knowledge tenure systems, which were an integral part of the social, political and economic framework which protect poor and vulnerable members. They also tended to disregard the empirical evidence that traditional tenure systems can be flexible and responsive to changing economic circumstances. Tenure insecurity is most acute among those using land to generate income, especially women.

5.13 Passing IKS to Children among Communities

The study identified that a number of methods were used to pass indigenous knowledge to the next generation. IK is passed on through oral methods via grandparents, parents, apprenticeship, general observation, folklore and learning by doing. These methods are not unique to those living in and within the Boni forest but are common among many indigneous people as reported inGordon & Krech, (2012). The study ascertained that indigenous knowledge was more often passed on by means of apprenticeship from the older to the younger generation than by any other means. This occurred during the hunting and gathering trips in the forests. As the older generation passes on, the knowledge goes with them as they are the main custodians of this information.

The study found out that the support required in enhancing utilization of medicinal and food plant species among the Boni included infrastructure, product development, market access, benefit sharing, training (on harvesting techniques), equipment, and financial resources.

The Boni expressed a desire to join networks of traditional medicine/medicinal plants (TMMP) which were quite strong in other parts of the country especially in the Rift Valley and which are receiving support from development partners and the Government. This would enable them to participate with other communities in the area of exchange of resources, experiences and knowledge (Gordon & Krech, 2012). At that moment they did not belong to any networks. This would provide an opening for diversification and also options for developing learning programmes.

5.14 Sacred Groves

The Boni, like the Ashanti of Ghana had sacred groves (Monroe & Ogundiran 2012). Among the Boni, sacred groves are parcels of land that are left untouched for spiritual purposes. They are often used as burial grounds and as a source of medicinal herbs, once the council of elders has approved. They also are generally locations of worship and communication between the traditional priests and the ancestors and gods. In Boni forest, members of public were barred from entering specific areas of the forest even in the same fashion as described by Gordon & Krech, (2012). Only elders were allowed to these areas. To reinforce those orders, children from an early age were told myths, folklore and stories of ogres and man eating cannibals in those areas. The men in the community also formed vigilante groups that patrolled the forest to prevent outsiders from accessing the sacred parts of the forest. This indirectly protected the plant species thus contributing to the conservation of biodiversity.

Besides the sacred groves, the Boni had specific areas in the forest for specific activities and these were further set apart for certain clans and linked to ancestral knowledge kept by specific clans. Social guidelines existed though not documented on how to utilize certain zones of the forest and its products. This has also been discussed by Matiku, (2000). The elders told the researcher that such knowledge was gleaned from years of experience interacting intimately with the forest and facing challenges that have often times included deaths of loved ones who entered the forest to hunt or gather and never came out alive. It was believed that their spirits released some of the knowledge being used in the dos and don’ts in the guidelines that the community adheres to in order to survive while in the forest. A narration of similar nature is found in Githitho, (2004). Part of the fundamental reasons for conservation of the forest rested on the fear instilled in the community from the outset claiming that the forest has ogres that destroyed anyone with ill intentions towards the forest. A number of elders attested to the fact that protection was needed in order to successfully navigate through the forest. Various elders offer such services at a modest fee thus controlling entry into and out of the forest. This was very useful and provided a gateway in future to both monitor and record harvesting of forest products. This also added to the question of whether it was possible for illegal logging to occur in an area that was this well controlled thus further propagating the thought that all illegal activities being undertaken in the forest was with the direct knowledge of the elders. The study noted the intricate knowledge held by the community on the health of the forest and how to maintain it.

Investigations into the traditional resource use norms and associated cultural institutions prevailing among the Boni demonstrated that a large number of elements of local biodiversity, regardless of their use value, were protected by the local cultural practices. Some of these may not have known conservation effect, yet may symbolically reflect a collective appreciation of the intrinsic or existence value of life forms, and the love and respect for nature.

Segregation of sacred groves aided in forest zonation. Rare species were protected in this ingenious way, taking advantage of the fear of spirits and dark forces that is a peculiar characteristic of the African. This has worked well among the Boni and one would not be wrong to conclude that control of access to natural resources using myths and the fear of repercussions from the anger of the gods has aided the course of conservation more than law enforcement has. The number of sacred groves was more in the forest of southern Ijara where 95% of them were recorded. Highly valued timber species like *A. quanzensis, T. spinosa and B huilensis* were still abundant in these areas and this could be attributed to the presence of these sacred groves much in line with the findings by Gordon & Krech, (2012). The results also agree quite well with the observations made by Hussein (2012) who noted that Sacred Natural Sites and Territories were at the heart of ecological, spiritual and cultural practices and governance systems of indigenous and local communities and have therefore resulted in the conservation of biodiversity in Kenya.

IKS are now being regarded as an invaluable national resource and within the development community, where indigenous knowledge systems provides opportunities for designing development projects that emerge from priority problems that have been identified and prioritized by the community and for the community, and which build upon and strengthen community-level knowledge systems and organizations (Musila, 2011; Warren & Cashman, 2012; Vogt, 2007).

IKS systems are diverse and according to Warren & Rajasekaran (1995) include:

a. Agricultural and natural resource management practices tested over time and suitable for sustainable development;
b. Adaptive skills of local people communicated through 'oral traditions' and learned through family members over generations derived from many years of experience;
c. Strategies and techniques developed by local people to cope with the changes in the socio-cultural and environmental conditions;
d. Practices that are accumulated by farmers due to constant experimentation and innovation;
e. Trial and error problem-solving approaches to meet the challenges they face in their local environments;
f. Decision-making skills of local people that draw upon the resources they have.

It is apparent that there is urgent need to support the Somali and Boni people to enhance the value of indigenous knowledge systems which currently is facing major challenges. The forest may remain under threat as long as the demand for food (including agricultural land, forest fruits, vegetables, nuts and bush meat) and industrial wood (furniture and wood carving by Lamu residents) are fundamental needs that must be met on a sustainable basis. With the looming impacts of a changing climate, these poor communities may find it very difficult to adapt as the indigenous systems they are used to may crush in the face of prolonged and frequent droughts.

CHAPTER SIX: SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary of Findings

6.1.1 Plant species composition and diversity

The forests in the study area are rich in plant species composition which implies richness in biodiversity. At least 300 plant species were recorded in the study, of which 130 were woody species. The species richness is more towards the southern parts of the study area. Here, the species diversity was higher and the similarity of species among study locations was higher. Forest stocking in terms of number of stems and tree basal areas was also higher in the forests south of Ijara as compared to those in the North. The forests of southern Ijara were more sustainable as compared to those of the north on the basis of vertical structure curves.

No single tree had an overall dominance over the others. Specific trees were dominant at specific study locations and on specific characteristics of dominance. Such a mixture of forests shows that some of the forest patches of Ijara Sub County are well conserved and the existing threats have not interfered with the floristic composition of the forest.

Species noted to be both dominant and with high species diversity indices include: *B. spiciformis* and *J. globiflora*, *C. molle*. These dominant as well as highly diverse tree and shrub species fit quite well within the general definition of coastal forests. However, species richness for some timber tree species such as *P.s angolensis, D. melanoxylon, P. rontundifolius,* and *A. verscolor* was very poor due to overexploitation. Harvesting of these species involves wood fuel collection and building materials like timber, poles and withies.

The composition and structure of the forest appeared superficially to be relatively uniform over large regions, suggesting a broad similarity in key environmental conditions. The uniformity in appearance was due in part to the remarkably similar physiognomy of the dominant canopy trees, no doubt a reflection of their origins in the Caesalpinioideae. Differences in species composition, diversity and structure were more apparent at a local scale. The origin of these differences was due to a number of factors including geomorphic, rapidly changing landscape, edaphic factors, with a major focus on soil moisture and soil nutrients, land use and other underlying causes and other anthropogenic pathways. The study particularly singled out the expanding agricultural scenarios and the policy to settle the Boni community inside the Forest as factors that had altered plant species diversity and composition.

Building focus on the woody species of the forest is fundamentalsince the existence of flora and fauna and other species (including humans) in the ecosystem largely depend on them to enhance their survival. In addition, woody species take much longer time to establish than almost every other plant species. Plant species composition data generated from this study will serve many important purposes especially in the national frameworks for decision making for more stringent and structured conservation and management of this forest.

6.1.2 Threats to Boni forest

The study has generated information on both potential and existing threats to the ecosystem which affect species richness. Frequent disturbance eliminates sensitive species, whereas very infrequent disturbance allows time for superior competitors to eliminate species that cannot compete. In the areas with evidence of impact of threats, species diversity and composition showed evidence of human influence mainly through indicators such as trees cut, poles cut, charcoal kilns, pit sawing, burnt areas and grazing.

Tree cutting was largely associated with local construction but there was also evidence of logging for timber. Illegal logging was also common in the closed forests with preference for specific species such as *T. spinosa*, *B. huilensis* and *A. quanzensis* being explicit. Regeneration of these species was very difficult, making their future very uncertain and threatened. Forestvegetation corresponds highly to the variations of rainfall and this affirms the fact that the vegetation has not been severely degraded through human activities.

Rates of biodiversity loss are clearly associated with a reduction in the extent of original habitat. The study has generated empirical evidence that shows that threat analysis generates more accurate estimates of species loss when conducted on a more local scale. Boni forests are vulnerable to stresses from habitat loss, uncharacteristic fires and climate change. New threats such as logging have emerged and old threats mainly from wild fires resurfaced.

Conversion of the Boni forests into agricultural land has led to detrimental ecological effects. Socio-economic drivers of land use change such as population totals and personal income levels have increased substantially. Human land use is the primary force driving changes in the Boni forest ecosystem attributes. Land use changes affecting the forests since 1990 have been heavily concentrated in the South.

Boni forest no doubt continues to play a significant role in environmental cleansing through carbon sequestration. Communities therefore have great potential to engage in activities like carbon trading which would offer alternative income generating means for the local community.

The study has established a baseline from which to monitor the change in status of species in Boni forest. It has also provided an in depth context for the establishment of conservation priorities that will further strengthen surveillance mechanisms of the forest. The study concludes that despite the actual and potential threats the Boni forest is facing, it continues providing goods and services to the surrounding communities and is still fairly well stocked with high tree and shrub species diversity, a fact attributed to the indigenous knowledge for biodiversity conservation.

6.1.3 Indigenous knowledge systems for conservation of biodiversity

The research examined the indigenous knowledge systems for conservation of biodiversity and demonstrates the value of the knowledge. The study also revisited the efficacy of traditional knowledge systems for conservation and identified challenges that the communities face and how local knowledge can be useful to address biodiversity conservation. The findings stress that indigenous knowledge systems is the fulcrum for decision making among the Boni in agriculture, healthcare, food preparation, education, natural resource management including a host of other activities. The study noted that the Boni are traditionally hunters and gatherers, rather than the typical Kenyan cattle herders. They depend entirely on nature for food and medicine with the central ingredient in their diet being honey, which they track down with the help of birds known by locals as "Mirsi" and commonly described as honey guides who feed on wax and bee larvae. This peculiar trait or unusual practice of using semi-domesticated birds to find honey, with whistling signals distinguishes them from other coastal tribes. They also eat wild fruits, roots and a variety of game which puts them at odds with wildlife officials.

Decision making takes place at the local level through indigenous organizations and associations where problems are identified and solutions determined. The study concludes that the local communities have evolved an indigenous knowledge system that is vital in conservation of the forest resources. The biological and social-economic importance of Boni forest is enormous and is in an area already marked as a hotspot yet has significant gaps in the biological knowledge. There are also important opportunities for further research, particularly with respect to forest structure and faunal composition. The diverse threats to woody species and the entire forest ecosystem require urgent multidimensional interventions from all the concerned agencies and relevant stakeholders.

6.2 Conclusions

Not many studies have been undertaken in Boni forest, so the findings of the research will be of immense value to the body of knowledge. The six transects used in the study represented both anthropogenic environments and ecosystems thus giving a very good opportunity to study species diversity and change causative factors, including indigenous knowledge systems for biodiversity conservation. The study has contributed to developing a species check list detailing the number of species found in each of these transects therefore providing a baseline from which future studies will be able to deduce the net changes in each region. The study has also analysed the threats to the ecosystem and documented indigenous knowledge systems for biodiversity conservation held by the communities living adjacent to the forest.

This research has unveiled certain fundamental issues: First, both the Boni and the Somali communities depend directly on their natural environment for livelihoods and other religious or spiritual purposes. Second, both communities have a wealth of valuable indigenous knowledge systems and experiences in conservation of biological diversity based on cumulative ideas and strategies that have been tested over long periods of time and proven of great advantage to survival of both the forest and biodiversity and the local community. Third, it also brought to light the interconnectedness between societal norms, community livelihoods and conservation within the sustainability framework. Finally the study has confirmed that the current levels of degradation in the forest had not surpassed the effects of climate change and the forest has the resilience to recover from the current levels of degradation. The significance of indigenous knowledge systems as a pillar in the conservation agenda has been clearly demonstrated by the study and emphasis on its usefulness especially in areas where the law enforcers are absent due to the insecurity and harsh environment made.

6.2.1 Plant species composition

The study concludes that the Boni Forest has a reasonably good tree and shrub species composition and richness. Boni forest provides goods and services to the surrounding communities and is the lifeline for both the Somali and the Boni people. The study further concludes that the forest is still fairly stocked with high tree and shrub species diversity.

6.2.2 Threats to Boni forest

Forest threats are on the rise and have potential to become numerous and widespread. They can disrupt the flow of goods and services from forests by affecting tree growth and survival, water quality and yield,drainage basin recharge and discharge capacity and biodiversity. The major threats in the forest were: (a) deforestation by shifting cultivation, (b) settlements in the forest area, (c) harvesting timber/logging, (d) grazing, (e) bush/forest fires and (f) illegal harvesting of building poles, in that order of priority.

The forest is used as a dry season grazing refuge by the larger Somali community residing as far as Garissa and its environs.

Forest fires were a major threat to the forest specifically in the southern part of the sub-county.Threats from fire were found to impact heavily on the following species: *D. melanoxylon, A. quanzensis, N. hildebrandtii, S. africana, T. spinosa, T. prunioides* and *A. drepanolobium.* These are trees highly vulnerable to fires due to their ease of combustion.

The number and variety of threats to biodiversity are important to know for identifying and applying an appropriate suite of conservation activities to an eco-region, but it is the cumulative impact of all threats that is of paramount importance for assessing trends in the viability and diversity of biological systems. There is enormous pressure on the Boni unique forest ecosystems for the expansion of farming, thus presenting economic conflict interests of the different stakeholders and threats, including the interest of the government in finding space to settle the minority Boni tribe.

At risk are forest genetic resources, medicinal values and services. These forest services can only be maintained and further developed on the condition that the unique forest ecosystem is given full protection status. Appropriate management of these genetic resources in the future will require: (1) understanding the existing genetic diversity/variation and population structure of forest trees, (2) understanding climatic change and its potential impacts on forest species and populations, and the ability to define forest populations and predict landscape-level effects of climate change is critical for sustaining future forest health. (3) development and use of new tools to identify populations at risk and geographic areas that will provide suitable habitat in the future.

It is evident that human, social and ecological change has taken place in the forest, changing and altering the species composition over time. Whether through simple extraction or low intensity farming, the cumulative long-term effects of these disturbances on forest composition and structure are real and have been significantly brought out by the study. The study concludes that a large proportion of the forest remains intact with no evidence of impact of threats, a factor attributed to conservation of biodiversity using indigenous knowledge systems, insecurity and the tsetse fly menace. Indigenous knowledge systemsare vital for sustainability of natural resources including forests, water, and agroecosystems across landscape continuum spanning from households through farms, villages and the forest.

6.2.3 Indigenous knowledge systems for biodiversity conservation

Indigenous knowledge systems are valuable and have become pivotal in preserving the identity and culture of the community especially among the Boni whose traditional way of life is under threat. The study has shown how the local communities in the study area conceptualize their interactions with the forest, construct their ethnobiological knowledge and alter and maintain the character of the forest through their activities.

Despite the presence of enormous indigenous knowledge that is extensively used in biodiversity conservation, there is notable decline in some plant species which the community attributes to overuse and exploitation over a long period of time. Increasing population as well as available markets for charcoal poses a major threat to the conservation of the forest. The need to create wealth and employment among the youth increases the pressure on the forest as they turn to charcoaling and timber logging. The study concludes that these are the result from an inadequate land-use planning and land tenure system, as the government did not consider the voice of the local community in forest management. Areas of the forest have been set aside for agriculture without taking into account the traditional forest use of local communities.

Traditional knowledge is a precious resource that they have sustainably tapped to conserve the landscape along with the biodiversity in the forests. These communities hold the power to either conserve or utterly decimate this ecosystem. They have interacted with the forest for centuries and made useful decisions that have so far resulted in its conservation.

The study concludes that the changing lifestyle towards modernization is a threat to indigenous conservation methods and this threatens the forest. The local community is experiencing changes in lifestyle, and land use activities specifically towards farming which is becoming the mainstay of the communities and this poses a threat to the forest since slash and burn farming methods are dominant. Activities like trading in timber which were unknown before have now gained ground in the area. The government has also initiated settlements in the forest and this not only reduces the forest area, but also promotes destruction of the forest in a number of ways.

The study further concludes that there is enormous indigenous knowledge systems among the Boni and Somali that exists for conservation of biological diversity. The community has over a long time accumulated knowledge of different species out of their day to day use including propagation of various plant species. Today, these indigenous knowledge systems are at risk of becoming extinct because of rapidly changing natural environments and fast pacing economic, political, and cultural changes. Practices vanish, as they become inappropriate for new challenges or because they adapt too slowly.

The study also concludes that indigenous knowledge systems are not yet fully utilized in the development process. Conventional approaches imply that development processes always require technology transfers from locations that are perceived as more advanced. This has led often to overlooking the potential in local experiences and practices.

The study makes the following conclusion: The indigenous knowledge systems out in the public domain are at risk of being lost and should be documented both for posterity and for immediate use in planning biodiversity conservation and management. There are certain types of indigenous knowledge systems not yet out in the public domain which remain a secret of the holders who are fast aging and some dying that should be inventoried and safeguarded in order not to lose it.

The biological and socio-economic importance of Boni forest is enormous and is the mainstay of both the Somali and Boni communities. The evidence in this study has demonstrated that indigenous knowledge systems/practices and local institutions complement each other. It is clear that local knowledge and associated practices continue to evolve and should be protected against breaking down and disappearing altogether through proper documentation. Boni Forest is among the East African Coastal forests which have long been isolated from other regions of tropical moist forests by expanses of drier savannas and grasslands, causing them to have an exceptionally high level of plant endemism that has recently led to part of it being classified as the Swahili Centre of endemism. The number of endemic species is thought to be greatly underestimated due to civil strife that has prevented further exploration.

6.3 Recommendations

6.3.1 Species composition and diversity

This study recommends further studiesonthe most used species to reduce the selection pressure on a small number of species currently under heavy exploitation. It is also important for the community to be assisted to establish seed banks while scientists establish gene banks for preservation of some of the plant species that are on the decline, more so those that do not propagate easily. The community holds great knowledge on how to propagate them from their trial and error methods and this knowledge can be helpful to botanists. Studies to prioritize genetic conservation efforts by using the populations at risk identified by this study should be undertaken.

Strategies should be mapped out to facilitate working with traditional land-holders, leaders/ opinion makers and their communities to facilitate, adapt and strengthen traditional mechanisms to conserve biodiversity in Boni forest under communal resource ownership scheme. County government in the spirit of devolution should strive to provide an enabling environment and strengthen government and non-government capacity to support community-based conservation initiatives and replicate successes throughout Boni forest. All stakeholders concerned to put forward efforts for helping to limit additional land degradation that threatens the continued provision of environmental services, livelihoods and economic well-being while at the same time promoting the conservation of the region's highly diverse biological resources.

6.3.2 Threats to ecosystem and biodiversity

The study recommends that Boni forest should be managed from one authority rather than the current arrangement. A Participatory Forest Management Plan (PFMP) should be developed for Boni forest. Inherent in the plan will be the formation of Community Forest Associations (CFAs) to enhance sustainable exploitation of forest products like honey, handicrafts and bush products.

The study recommends that money be set aside to build the communities resilience to climate change as a measure towards reduction of threats to the forest and the wider ecosystem including improved livelihoods.

6.3.3 Indigenous knowledge systems for biodiversity conservation

It isrecommended that the Department of Gender, Culture and Social Services of Ijara Sub County links the Boni with other networks of traditional medicinal plants within the country to enable them to learn and share knowledge with others who have similar practices and are benefiting from it. They should first be linked to the network of herbalists at the Coast.

The study recommends that the government when formulating policies, legislation, plans, programmes and strategies should mainstream indigenous knowledge systems into each of them. The study further recommends that climate change adaptation should be mainstreamed into development planning at both the local and county levels. The County government under whose jurisdiction Boni forest falls should seize the opportunity and incorporate this in respective county environmental / climate change policies in line with devolution.

The study further recommends that the sub county of Ijara promotes sound agricultural practices utilizing traditional knowledge held by indigenous communities especially in the management of livestock and rangelands including grazing season refuges.

Additional recommendations include the following:

i. Incorporating indigenous knowledge systems in formal learning which can take the form of using folklore, story telling, proverbs and sharing of good practices among others from the local community.
ii. Promoting capacity development of indigenous and local communities, this will help in catalyzing sustainability of Boni forest ecosystem.
iii. Continuous documentation of the indigenous knowledge systems..
iv. The study recommends the importance of augmenting conservation measures in order to safeguard the ecosystem services that biodiversity provides and human society needs.

6.4 Further research

6.4.1 Plant species composition and diversity

Further research should be undertaken in the following areas:

Propagation of plant species used as food during prolonged drought periods. This includes species such as *B. cathatica*.

Determine the chemical composition and efficacy of the listed medicinal plants.

To enhance utilization of medicinal and food plant species among the Boni, there is urgent need for further research on product development such as packaging of the herbal medicine into the right quantities, market access, benefit sharing.

Further research to develop vegetative methods of propagation of *A. senegal* and *A. seyal* to enhance selection and breeding programmes aimed at producing superior gum-yielding trees.

6.4.2 Threats to ecosystem and biodiversity/

Research on the cross border impacts on the shared ecosystem with Somalia. This will entail exploring the possibility of developing a joint forest management plan.

The cross border effects the forest faces from the border with Somalia need to be further analyzed to ascertain all claims and develop measures to restore, rehabilitate and increase forest cover. In future, a joint management plan with Somalia will bear huge dividends to conservation of the forest and its biodiversity and peoples.

6.4.3 Indigenous knowledge systems for biodiversity conservation

Further research into the cross border relationships with the tribes in the Republic of Somalia will also be extremely useful and may reveal transboundary information significant in developing conservation programmes based on IKS.

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APPENDICES

APPENDIX 1 A: BONI FOREST THREAT ANALYSIS DATA COLLECTION FORMAT

Recorder___________ Transect Name & No. _____________ Date______

Quadrat size _________ Belt GPS_______________________________

Approximate distance from the nearest settlement or Boma ----------------------

Approximate distance to the nearest sacred site ---------------------------

Plant related disturbances

QD No.	Species	Cut stump Diam (cm)	Cut stump age	Cut branch No.	No. of Debarking marks	Honey harvest

Environmental/other disturbances

QD	Charcoal kiln No.	sawing pit No.	Foot path No.	Cattle track No.	Dung Levels (l/m/h)	Cultivation (y/n)	Burning (y/n)

Other observations

APPENDIX 1B: COMMUNITY SURVEY TOOLS (QUESTIONNAIRES)

QUESTIONNAIRE ON INDIGENOUS KNOWLEDGE FOR CONSERVATION OF BIOLOGICAL DIVERSITY IN BONI FOREST

Questionnaire No.……..Interviewer……………………..…. Location ………… Date………

Introduction

This questionnaire is to solicit information on vegetation characteristics and indigenous knowledge for conservation of biological diversity in Boni forest and it is purely for academic purposes. All the information gathered will be treated with utmost care and confidentiality. Your help is highly appreciated. Thank you.

Personal information

Community	**Sex**	**Age**	**Education**	**Occupation**

Threats to forest biodiversity conservation in Boni forest

Category/types	**Level (rating)**	**Causes**	**Actors**	**Impacts**	**Current interventions**	**Proposed interventions**

Indigenous knowledge

Typology and selected features of indigenous knowledge in biodiversity conservation at community level

Areas of Knowledge (examples)	**Bearers of knowledge**	**Manifestation of knowledge (examples)**	**Contribution to biodiversity conservation**	**Potential (of adoption)IK in biodiversity conservation**	**Constraints and problems**

Typology and selected features of indigenous knowledge in plant species utilization at community level

Areas of Knowledge (examples)	Bearers of knowledge	Manifestation of knowledge (examples)	Contribution to sustainable utilization of plant species	Potential of IK adoption in sustainable utilization plant species	Constraints and problems

Dissemination of indigenous knowledge on biodiversity conservation plant species utilization

Actors and mode of transfer	Means and media of transfer	Context of transfer	Content	Potential for dissemination of knowledge	Constraint and problems to transfer of IK

Utilization of plant species

Species	Uses	User	Application of IK in the utilization	Threats	

APPENDIX 2: CODES FOR SHORTENED SPECIES NAMES

A. bussei	*A. buss*
A. digitata	*A. digi*
A. mellifera	*A. mell*
A. nilotica	*A. nilo*
A. quanzensis	*A. quan*
A. reficiens	*A refi*
A. seyal	*A. seya*
A. tortilis	*A. tort*
B. aegyptiaca	*B. aegy*
B. angustifolia	*A. angu*
B. tomentosa	*B. tome*
B. wilsoniana	*B. wils*
C. constrictum	*C. cons*
C. edulis	*C. edul*
C. nilotica	*C. nilo*
C. schumannii	*C. schu*
D melanoxylon	*D. mela*
D. cornii	*D. corn*
D. glabra	*D. glab*
D. orientale	*D. orie*
L. stuhlmannii	*L. stuh*
M. mochisia	*M. moch*
M. sulcata	*M. sulc*
N. elata	*N. elat*
N. erlangeri	*N. erla*
N. hildebrandtii	*N. hild*
O. somalensis	*O. soma*
S. africana	*S. afri*

S. capense	*S. cape*
S. madagascariensi	*S. mada*
S. persica	*S. pers*
T. danis	*T. dani*
T. spinosa	*T. spino*
A. reficiens	*A. refi*
B. huilensis	*B. huil*
C. Africana	*C. afr*
C. bibracteatum	*C. bibra*
C. brevispica	*C. bre*
C. euryoides	*E eury*
C. illairii	*C. illa*
C. pseudopulchellus	*C. pse*
D. glabra	*D.glab*
G. plagiophylla	*G. plagi*
H. zeylanica	*H. zeyl*
L. scweinfurthii	*L. Scwe*
M. zanguebarica	*M. Zang*
N. erlangeri	*N erla*
O. thomasiana	*O. thom*
T. graveolens	*T. grav*

APPENDIX 3: NDVI DATA FOR WOODY VEGETATION IN BONI FOREST FOR 1999-2011

Date	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
10-Jan	0.56	0.69	0.62	0.61	0.63	0.66	0.67	0.62	0.68	0.67	0.59	0.73	0.60
20-Jan	0.57	0.67	0.63	0.58	0.61	0.63	0.63	0.56	0.67	0.65	0.54	0.71	0.58
30-Jan	0.55	0.64	0.59	0.55	0.56	0.57	0.58	0.54	0.68	0.63	0.50	0.69	0.58
10-Feb	0.50	0.66	0.55	0.53	0.56	0.53	0.54	0.53	0.65	0.62	0.47	0.60	0.55
20-Feb	0.46	0.63	0.52	0.50	0.55	0.49	0.51	0.48	0.61	0.58	0.45	0.59	0.53
28-Feb	0.44	0.58	0.50	0.49	0.51	0.47	0.50	0.44	0.55	0.53	0.43	0.55	0.50
10-Mar	0.42	0.55	0.46	0.49	0.48	0.43	0.46	0.45	0.53	0.52	0.44	0.54	0.46
20-Mar	0.42	0.53	0.50	0.49	0.50	0.43	0.46	0.44	0.48	0.51	0.43	0.53	0.44
30-Mar	0.45	0.52	0.55	0.51	0.51	0.47	0.46	0.47	0.45	0.53	0.44	0.61	0.44
10-Apr	0.48	0.55	0.56	0.54	0.52	0.50	0.47	0.52	0.45	0.59	0.47	0.61	0.47
20-Apr	0.52	0.54	0.59	0.57	0.54	0.52	0.51	0.58	0.50	0.64	0.50	0.61	0.50
30-Apr	0.55	0.55	0.64	0.58	0.56	0.55	0.57	0.61	0.53	0.66	0.51	0.64	0.55
10-	0.61	0.59	0.63	0.61	0.55	0.55	0.58	0.65	0.59	0.66	0.55	0.68	0.61

May													
20-May	0.64	0.59	0.63	0.64	0.58	0.54	0.62	0.62	0.62	0.68	0.59	0.68	0.64
30-May	0.64	0.60	0.65	0.64	0.59	0.53	0.65	0.60	0.66	0.68	0.62	0.70	0.65
10-Jun	0.64	0.65	0.65	0.63	0.62	0.55	0.65	0.62	0.68	0.65	0.64	0.75	0.64
20-Jun	0.65	0.67	0.64	0.64	0.64	0.58	0.64	0.63	0.69	0.66	0.65	0.74	0.60
30-Jun	0.60	0.65	0.66	0.64	0.66	0.63	0.67	0.61	0.68	0.68	0.65	0.73	0.58
10-Jul	0.56	0.63	0.67	0.63	0.65	0.67	0.67	0.64	0.70	0.67	0.64	0.72	0.56
20-Jul	0.57	0.62	0.67	0.64	0.66	0.70	0.67	0.66	0.69	0.65	0.64	0.70	0.56
30-Jul	0.56	0.60	0.66	0.64	0.64	0.71	0.67	0.65	0.67	0.66	0.62	0.69	0.55
10-Aug	0.54	0.58	0.65	0.63	0.62	0.71	0.70	0.63	0.67	0.65	0.63	0.64	0.54
20-Aug	0.56	0.57	0.63	0.60	0.59	0.69	0.67	0.63	0.65	0.64	0.58	0.63	0.52
30-Aug	0.60	0.57	0.62	0.57	0.57	0.67	0.64	0.62	0.62	0.59	0.54	0.61	0.49
10-Sep	0.60	0.54	0.60	0.56	0.54	0.65	0.61	0.60	0.62	0.56	0.50	0.60	0.46
20-Sep	0.59	0.52	0.56	0.54	0.48	0.62	0.60	0.58	0.60	0.54	0.47	0.56	0.44
30-Sep	0.57	0.51	0.55	0.52	0.46	0.59	0.55	0.57	0.59	0.50	0.43	0.54	0.45
10-	0.56	0.53	0.54	0.50	0.44	0.58	0.53	0.56	0.61	0.48	0.43	0.50	0.50

Oct													
20-Oct	0.52	0.53	0.52	0.51	0.45	0.58	0.53	0.54	0.61	0.45	0.50	0.47	0.53
30-Oct	0.49	0.54	0.51	0.53	0.49	0.59	0.54	0.56	0.61	0.44	0.55	0.47	0.56
10-Nov	0.47	0.58	0.51	0.55	0.53	0.62	0.55	0.57	0.62	0.47	0.60	0.50	0.60
20-Nov	0.46	0.59	0.53	0.58	0.59	0.66	0.58	0.61	0.63	0.52	0.67	0.54	0.65
30-Nov	0.50	0.60	0.57	0.63	0.66	0.69	0.62	0.62	0.64	0.56	0.71	0.59	0.63
10-Dec	0.57	0.61	0.60	0.67	0.69	0.71	0.64	0.69	0.67	0.60	0.69	0.62	0.65
20-Dec	0.61	0.62	0.61	0.64	0.68	0.73	0.62	0.71	0.66	0.65	0.70	0.61	0.68
30-Dec	0.64	0.61	0.62	0.62	0.67	0.73	0.60	0.73	0.66	0.65	0.73	0.60	0.70

S/N	Species checklist
1	Abrus precatorius
3	Abutilon hirtum (Lamarck)
4	Acacia brevispica (Harms.)
5	Acacia bussei Harms
6	Acacia drepanolobium
7	Acacia elatior Brenan
8	Acacia mellifera (Vahl) Benth
10	Acacia nilotica (L.) Willd. ex Delile
11	Acacia reficiens Wawra
12	Acacia robusta (Burch.)
14	Acacia senegal (L.) Willd. Syn
15	Acacia seyal Del.
16	Acacia sieberiana var.woodii
17	Acacia tortilis Hayne
18	Acacia volkensii
19	Acacia xanthophloea Benth.
20	Acalypha indica
22	Achyranthes aspera
21	Acridocarpus zanzibaricus
23	Adansonia digitata L.
24	Adenia venenata
25	Adenium obesum Forssk.
26	Aerva javanica
27	Aerva lanata
28	Aerva leucura
29	Aerva persica
30	Aeschynomene uniflora
31	Afzelia quanzensis Welw.
32	Albizia glaberrima
33	Allophylus petiolatus Radlk.

34 Allophylus rubifolius
35 Alysicarpus glumaceus
36 Ampelocissus Africana
37 Aneilema aequinoctiale
38 Aneilema petersii
39 Anglocalyx braunnii
40 Antidesma venosum
41 Apodytes dimidiata
42 Aristida adscensionis
43 Aristida stenostachya
44 Arthrocnemum indicum
45 Aspilia macrorrhiza
46 Asteranthe asterias (S. Moore)
47 Asystasia gangetica
48 Avicennia marina
49 Azadirachta indica
50 Azima tetracantha
51 Balanites aegyptiaca (L.) Del. (Hingot)
52 Balanites wilsoniana Dawe & Sprague
53 Basananthe lanceolata
54 Blepharis maderaspatensis
55 Borassus aethiopium Mart.
57 Boscia angustifolia A. Rich.
58 Boscia coriacea
59 Boscia tomentosa Toelken
60 Bourreria nemoralis
61 Brachiaria deflexa
63 Brachiaria leersiodes
62 Brachiaria leucacrantha
64 Brachylaena huillensis O. Hoffm.
66 Bridelia cathartica G. Bertol

67	Bridelia scleroneura
68	Bruguiera gymnorrhiza
70	Buxus obtusiflolia (Mildbr.) Hutch
72	Cadaba farinosa Forssk
74	Canavalia rosea
76	Canthium bibracteatum (Baker) Hiern
77	Canthium kilifiense (Bridson) Lantz
78	Canthium pseudoverticillatum S.Moore
73	Caperonia fistulosa
79	Capparis sepiaria (L.) R.Br.
80	Capparis viminea
81	Cardiospermum halicacabum
82	Cassia abbreviata
83	Cassipourea euryoides
84	Cassipourea euryoides Alston.
85	Cassytha filiformis
87	Catunaregam nilotica (Staphf)
88	Celosia schweinfurthiana
89	Cenchrus ciliaris
90	Cenchrus mitis
91	Centrostachys aquatic
92	Ceriops tagal
93	Chamaecrista mimosoides
94	Chloris mossambicensis
95	Chloris roxyburgiana
96	Chlorophytum filipendulum
97	Cissus integrifolia
98	Cissus rotundifolia
99	Cistanche tubulosa
100	Cladostemon kirkii
101	Clerodendron myricoides

102 Clerodendrum cephalanthum
103 Clerodendrum incisum
104 Cola clavata
105 Cola minor Brenan
106 Coldenia procumbens
108 Combretum constrictum (Benth)
110 Combretum illairii Engl.
111 Combretum schumannii Engl.
113 Commiphora africana (A. Rich) Engl. Syn
114 Commiphora alata Chiov.
115 Commiphora boiviniana
116 Commiphora edulis (Klotzsch) Eng
117 Commiphora pteleifolia
118 Commiphora schimperi
119 Commiphora trothae
120 Cordia monoica
121 Cordia sinensis
122 Cordia somaliensis
123 Cordia subcordata
125 Craibia brevicaudata (Vatke) Dunn
126 Cressa cretica
127 Crotalaria boranica
128 Crotalaria distantiflora
129 Crotalaria emarginata
130 Crotalaria laburnifolia
131 Crotalaria madurensis Wight & Arn
132 Crotalaria malindiensis
133 Crotalaria retusa
134 Crotalaria ukambensis
135 Croton megalocarpus Hutch.
136 Croton polytrichus Pax

137 Croton pseudopulchellus Pax.
140 Croton talaeporos Radcl.
142 Cussonia zimmermannii Harms
143 Cyathula coriacea
144 Cyclosorus dentatus
145 Cymbopogon caesius
146 Cymodocea rotundata
147 Cynanchum hastifolium
148 Cyperus compressus
149 Cyperus denudatus
150 Cyperus grandis
151 Cyperus haspan
152 Cyperus sp.
153 Cyperus tenuispica
154 Cyphia glandulifera
155 Dactyloctenium australe
156 Dactyloctenium ctenioides
157 Dactyloctenium geminatum
159 Dalbergia melanoxylon Guill. et Perrott.
160 Dalbergia vacciniifolia Vatke
161 Datura metel
162 Dialium orientale Bak. f.
163 Dichrostachyus cinerea
165 Didymosalpinx norae
166 Digera muricata
167 Digitaria argyrotricha
168 Digitaria milanjiana
169 Diodia aulacosperma
170 Dioscorea histiflora
172 Diospyros consolatae Chiov.
173 Diospyros cornii Chiov.

174	Diospyros mespiliformis
175	Diospyros natalensis
176	Diospyros spp.
177	Diospyros squarrosa
178	Dobera glabra Forssk.
179	Dobera loranthifolia
180	Dombeya praetermissa
182	Drypetes natalensis (Harv.) Hutch
183	Ecbolium armplexicaule
184	Ecbolium striatum
185	Ecbolium viride
186	Eclipta prostrate
188	Ehretia bakeri Britten
189	Ehretia cymosa
190	Ehretia littoralis
191	Ehretia petiolaris
192	Ekebergia capensis Sparrm.
193	Elaeodendron schweinfurthianum
194	Emilia discifolia
195	Encephalartos hildebrandtii A.Braun
196	Enicostema axillare
197	Enteropogon sechellensis
198	Eragrostis caespitosa
199	Eragrostis ciliaris
200	Eriosema glomeratum
201	Eriosema parviflorum
203	Erythrina sacleuxii Hua
204	Erythrophleum suaveolens (Guill. & Perr.)
205	Erythroxylon emarginatum
206	Euclea natalensis A.DC.
207	Euclea schimperi

208	Euphorbia candelubrum Kotschy
210	Euphorbia cuneata Vahl
211	Euphorbia prostrata
212	Evolvulus alsinoides
214	Excoecaria bussei Pax
215	Fernandoa magnifica
216	Ficus changuensis
217	Fimbristylis dichotoma
218	Fimbristylis exilis
219	Fluggea virosa
220	Fuirena ciliaris
222	Garcinia livingstonei Anders
223	Garcinia volkensii Engl
224	Gardenia jovis-tonantis
225	Gardenia ternifolia
226	Gardenia volkensii K.Schum
227	Gisekia africana
228	Glinus lotoides
229	Grandidiera boivinii
231	Grewia plagiophylla K. Schum
233	Grewia stuhlmannii K.Schum.
234	Grewia vaughanii
235	Hackelochloa granularis
236	Halophila balfouri
237	Halopyrum mucronatum
239	Haplocoelum foliolosum (Hiern) Bullock
241	Haplocoelum inoploeum Radlk.
243	Harrisonia abyssinica Oliv.
244	Heliotropium albohispidum
245	Heliotropium spp.
246	Heliotropium subulatum

247	Hermannia exappendiculata
248	Heteropogon contortus
249	Hewittia sublobata
250	Hibiscus cannabinus
251	Hibiscus micranthus
252	Hildebrandtia obcordata
253	Hippocratea Africana
254	Hippocratea crenata
255	Homalium abdessamadii Aschers. & Schweinf
256	Hugonia castaneifolia
258	Hunteria zeylanica (Retz.) Gardener ex Thw
259	Hybanthus densifolius
260	Hybanthus enneaspermus
261	Hygrophilla auriculata
262	Hyperthelia dissoluta
263	Hyphaene compressa H. Wendl.
265	Hyphaene coriacea Gaertn
266	Indigofera brachynema
267	Indigofera cliffordiana
268	Indigofera microcarpa
269	Indigofera schimperi
270	Indigofera tanganyikensis
271	Indigofera tinctoria
272	Indigofera trita
273	Indigofera wituensis
274	Inhambanella henriquerii
276	Ipomoea fistulosa
277	Ipomoea lapathifolia
278	Ipomoea obscura
279	Jacquemontia tamnifolia
280	Jatropha spicata

281 Justicia flava
282 Justicia stachytarphetoides
283 Keetia zanzibarica
284 Kigelia africana (Lam.)
285 Kohautia caespitosa
287 Kraussia kirkii (Hook.f.) Bullock
288 Kraussia speciosa
289 Lagarosiphon tenuis
290 Lamprothamnus zanguebaricus
292 Lannea alata (Engl.) Engl.
294 Lannea schweinfurthii (Engl.) Engl.
295 Lannea stuhlmannii (Engl.) Engl.
296 Lannea welwitschii (Hiern) Engl
297 Lantana viburnoides
298 Lasiodiscus mildbraedii
299 Launaea intybacea
300 Launaea sarmentosa
301 Lawsonia inermis Linn.
303 Lecaniodiscus fraxinifolius Baker.
304 Lepisanthes senegalensis
305 Lepturus radicans
306 Lepturus repens
307 Lightfootia napiformis
308 Lippia somalensis
309 Lobelia fervens
311 Lonchocarpus bussei Harms
312 Lumnitzera racemosa
313 Maerua angolensis
314 Maerua calantha
315 Maerua oblongifolia
316 Maerua triphylla

318 Majidea zanguebarica Kirk ex D. Oliver
319 Manilkara mochisia (Baker) Dubard
321 Manilkara sulcata (Engl.) Dubard
322 Mariscus phillipsiae
323 Mariscus pseudovestitus
324 Markhamia zanzibarica
326 Maytenus mossambicensis Klotzsch Blakelock
328 Maytenus undata Thunb. Blakelock
329 Megastachya mucronata
330 Melhania taylori
331 Melhania velutina
332 Merremia tridentata
333 Milicia excels
334 Monechma debile
335 Moringa stenopetala (Baker f.) Cufodontis
337 Mystroxylon aethiopicum, (Thunb.)
338 Nectaropetalum kaessneri Engl
339 Neptunia oleracea
340 Newtonia erlangeri (Harms) Brenan
341 Newtonia hildebrandtii (Vatke) Torre
342 Ochna mossambicensis
343 Ochna ovate
345 Ochna thomasiana Engl. & Gilg
346 Ocimum viride
347 Odontella kelleri
348 Odontella spp.
350 Oldfieldia somalensis Chiov. Milne-Redh.
351 Oliverella hildebrandtii
352 Operculina trupethum
353 Ophioglossum costatum
354 Ophioglossum gomezianum

356	Ormocarpum kirkii S. Moore
357	Oryza longistaminata
358	Oryza punctata
359	Oxygonum atriplicifolium
360	Oxygonum salicifolium
361	Ozoroa obovatum
362	Pachystela verticillata
363	Panicum astrosanguineum
364	Panicum coloratum
365	Panicum deustum
366	Panicum hippothrix
367	Panicum infestum
368	Panicum maximum
369	Panicum pinifolium
370	Panicum trichocladum
371	Paspalum scrobiculatum
372	Paulinia pinnata
373	Pavonia mollissima
374	Pavonia zeylanica
375	Pedalium murex
376	Pellaea adiantoides
377	Pennisetum polystachyon
378	Pentatropis spiralis
379	Pentodon pentandrus
380	Peponium vogelli
381	Peristrophe bicalyculata
382	Perotis patens
383	Phyllanthus reticulata
384	Platycerium angolense
385	Plicosepalus curviflorus
386	Pluchea sordid

387 Plumbago stenophylla
388 Polycarpaea grahamii
389 Polycarpaea spicata
390 Polysphaeria multiflora
391 Polysphaeria parvifolia
392 Populus ilicifolia
393 Portulaca pilosa
394 Premna resinosa
395 Premna velutina
396 Psilotrichum sericeum
397 Psychotria punctata
398 Psychotria riparia
399 Pycreus pumilus
400 Pyrenancantha malvifolia
401 Rauvolfia mombasiana Stapf
402 Rhizophora mucronata
403 Rhoicissus revoilii
404 Rhus natalensis
405 Rhynchelytrum repens
406 Rhynchosia hirta
407 Rhynchosia velutina
408 Rinorea ilicifolia (Welw. ex Oliv.)
409 Rinorea squamosa
410 Rourea coccinea
411 Rourea orentalis
412 Ruellia patula
413 Sacciolepis curvata
414 Salacia madagascariensis (Lam.) DC.
415 Salicornia pachystachya
416 Salvadora persica L.
417 Scaveola plumieri

418 Scaveola taccada
419 Schizachyrium sanguineum
420 Schlechterina mitostemmatoides
421 Schoenefeldia transiens
422 Schoennefeldia transiens
423 Scirpus confuses
424 Senecio billiodes
425 Senna siamea
426 Sesamum calycimum
427 Sesbania bispinosa
428 Sesbania keniensis
429 Setaria incrassate
430 Sida acuta
431 Sideroxyylon inerme Baker
432 Solanum goetzei
433 Solanum hastifolium
434 Solanum pampaninii
435 Solanum spp.
436 Sophora tomentosa
437 Sorghum versicolor
438 Sorindeia madagascariensis
439 Spermacoce filituba
440 Sphaeranthus ukambensis
441 Sporobolus kentrophyllus
442 Spragueanella rhamnifolia
443 Stathmostelma pedunculatum
444 Sterculia africana Lour.
445 Sterculia appendiculata K.Schum
446 Striga gesnerioides
447 Strobopetalum bentii
448 Strychnos decussata Pappe Gilg

449 Strychnos henningsii Gilg
450 Strychnos madagascariensis
451 Strychnos spinosa Lam.
452 Suregada zanzibariensis Baill
453 Synaptolepis kirkii
454 Synsepalum subverticillatum Bruce &Penn
455 Tabernaemontana elegans Stapf.
456 Talinum portulacifolium
457 Tamarindus indica L. Tamarindo.
458 Tapinanthus sansibarensis
459 Tarenna graveolens (S.Moore)
460 Tarenna trichantha
461 Teclea nobilis Del.
462 Teclea trichocarpa (Engl.) Engl
463 Tecoma stans
464 Tephrosia nubica
465 Tephrosia pumila
466 Tephrosia purpurea
467 Tephrosia villosa
468 Terminalia cuneata Roth.
469 Terminalia prunioides Lawson
470 Terminalia superba Engl. et Diels
471 Thespesia danis Oliv.
472 Thespesia populnea
473 Thylachium africanum
474 Thylachium thomasii
475 Tinnea aethiopica
476 Trianthema triquetra
477 Tribulus terrestris
478 Trichilia emetic
479 Turraea nilotica

480 Urochloa trichopus
481 Uvaria acuminata Oliv.
482 Uvaria denhardtiana Engl. & Diels
483 Uvaria lucida
484 Vahlia dichotoma
485 Vernonia hildebrandtii
486 Vernonia homilantha
487 Vigna membranacea
488 Vigna unguiculata
489 Vitex carvalhi
490 Vitex ferruginea Schumach. & Thonn.
491 Vitex mombassae
492 Waltheria indica
493 Warburgia stuhlmannii Engl.
494 Ximenia americana L.
495 Xylocarpus granatum
496 Xylocarpus moluccensis
497 Zaleya pentandra
498 Zanthoxylum chalybeum
499 Ziziphus mauritiana Lam.
500 Ziziphus mucronata

APPENDIX 4: LIST OF PLANT SPECIES IDENTIFIED IN BONI FOREST AND THEIR FAMILIES (2012)

8 ANNONACEAE
Uvaria acuminate
Uvaria lucida
11 LAURACEAE
Cassytha filiformis
36 CAPPARACEAE
Boscia angustifolia
Boscia coriacea
Cadaba farinosa
Capparis viminea
Cladostemon kirkii
Maerua angolensis
Maerua calantha
Maerua oblongifolia
Maerua triphylla
Thylachium africanum
Thylachium thomasii
40 VIOLACEAE
Hybanthus densifolius
Hybanthus enneaspermus
Rinorea squamosa
47 VAHLIACEAE
Vahlia dichotoma
53 CARYOPHYLLACEAE
Polycarpaea grahamii
Polycarpaea spicata
Aerva lanata
Aerva leucura
Aerva persica
Celosia schweinfurthiana
Centrostachys aquatic
Cyathula coriacea
Digera muricata
Psilotrichum sericeum
66 ZYGOPHYLLACEAE
Tribulus terrestris
81 THYMELAECEAE
Synaptolepis kirkii
93 FLACOURTIACEAE
Grandidiera boivinii
101 PASSIFLORACEAE
Adenia venenata
Basananthe lanceolata
Schlechterina mitostemmatoides
103 CUCURBITACEAE
Peponium vogelli
114 OCHNACEAE
Ochna mossambicensis
Ochna ovate
Ochna thomasiana
121 COMBRETACEAE
Combretum constrictum
Hermannia exappendiculata
Melhania taylori
Melhania velutina
Sterculia Africana
Waltheria indica
132 MALVACEAE
Abutilon hirtum
Hibiscus cannabinus
Hibiscus micranthus
Pavonia mollissima
Pavonia zeylanica
Sida acuta
Thespesia danis
Thespesia populnea
133 MALPHIGIACEAE
Acridocarpus zanzibaricus
135 ERYTHROXYLACEAE
Erythroxylon emarginatum
Hugonia castaneifolia
136 EUPHOBIACEAE
Acalypha indica
Antidesma venosum
Bridelia scleroneura
Caperonia fistulosa
Croton pseudoputchellus
Croton talaeporos

55 AIZOACEAE

Gisekia Africana

Glinus lotoides

Trianthema triquetra

Zaleya pentandra

56 PORTLACACEAE

Portulaca pilosa

Talinum portulacifolium

57 POLYGONACEAE

Oxygonum atriplicifolium

Oxygonum salicifolium

61 CHENOPODIACEAE

Arthrocnemum indicum

Salicornia pachystachya

63 AMARANTHACEAE

Achyranthes aspera

Aerva javanica

Albizia glaberrima

Dichrostachyus cinerea

Neptunia oleracea

148 PAPILIONACEAE

Abrus precatorius

Aeschynomene uniflora

Alysicarpus glumaceus

Anglocalyx braunnii

Canavalia rosea

Craibia brevicaudata

Crotalaria boranica

Crotalaria distantiflora

Crotalaria emarginata

Combretum illairii

Lumnitzera racemosa

Terminalia prunoides

122 RHIZOPHORACEAE

Bruguiera gymnorrhiza

Cassipourea euryoides

Ceriops tagal

Rhizophora mucronata

126 GUTTIFERAE

Garcinia livingstonei

128 TILIACEAE

Grewia plagiophylla

Grewia stuhlmannii

Grewia vaughanii

130 STERCULIACEAE

Cola clavata

Dombeya praetermissa

156 SALICACEAE

Populus ilicifolia

167 MORACEAE

Ficus changuensis

Milicia excels

173 CELASTRACEAE

Elaeodendron schweinfurthianum

Hippocratea Africana

Hippocratea crenata

Maytenus mossambicensis

Maytenus undata

Mystroxylon aethiopicum

Salacia madagascariensis

Drypetes natalensis

Euphorbia cuneata

Euphorbia prostrate

Excoecaria bussei

Fluggea virosa

Jatropha spicata

Oldfieldia somalensis

Phyllanthus reticulate

Suregada zansibarensis

146 CAESALPINIACEAE

Cassia abbreviate

Chamaecrista mimosoides

Senna siamea

Tamarindus indica

147 MIMOSACEAE

Acacia nilotica

Acacia Senegal

Commiphora schimperi

Commiphora trothae

197 MELIACEAE

Azadirachta indica

Trichilia emetic

Turraea nilotica

Xylocarpus granatum

Xylocarpus moluccensis

198 SAPINDACEAE

Allophylus rubifolius

Cardiospermum halicacabum

Haplocoelum foliolosum

Haplocoelum inoploeum

Crotalaria laburnifolia
Crotalaria malindiensis
Crotalaria retusa
Crotalaria ukambensis
Dalbergia melanoxylon
Eriosema glomeratum
Eriosema parviflorum
Erythrina saccleuxii
Indigofera brachynema
Indigofera cliffordiana
Indigofera microcarpa
Indigofera schimperi
Indigofera tanganyikensis
Indigofera tinctoria
Indigofera trita
Indigofera wituensis
Lonchocarpus bussei
Ormocarpum kirkii
Rhynchosia hirta
Rhynchosia velutina
Sesbania bispinosa
Sesbania keniensis
Sophora tomentosa
Tephrosia nubica
Tephrosia pumila
Tephrosia purpurea
Tephrosia villosa
Vigna unguiculata
Vigna membranacea

154 BUXACEAE

Buxus obtusiflolia

179 ICACINACEAE

Pyrenancantha malvifolia

180 SALVADORACEAE

Azima tetracantha
Dobera loranthifolia
Salvadora persica.

182 OLACACEAE

Ximenia Americana

185 LORANTHACEAE

Odontella kelleri
Odontella spp.
Oliverella hildebrandtii
Plicosepalus curviflorus
Spragueanella rhamnifolia
Tapinanthus sansibarensis

190 RHAMNACEAE

Lasiodiscus mildbraedii
Ziziphus mauritiana
Ziziphus mucronata

193 VITACEAE

Ampelocissus Africana
Cissus integrifolia
Cissus rotundifolia
Rhoicissus revoilii

194 RUTACEAE

Zanthoxylum chalybeum

195 SIMAROUBACEAE

Harrisonia abyssinica

196 BURSERRACEAE

Commiphora africana
Commiphora boiviniana
Lecaniodiscus fraxinifolius
Lepisanthes senegalensis
Majidea zanguebarica
Paulinia pinnata

205 ANACARDIACEAE

Lannea alata
Lannea schweinfurthii
Ozoroa obovatum
Rhus natalensis
Sorindeia madagascariensis

206 CONNARACEAE

Rourea coccinea
Rourea orentalis

212 ARALIACEAE

Cussonia zimmermannii

221 EBENACEAE

Diospyros consolatae
Diospyros mespiliformis
Diospyros natalensis
Diospyros spp.
Diospyros squarrosa

222 SAPOTACEAE

Euclea schimperi
Inhambanella henriquerii
Manilkara sulcata
Pachystela verticillata
Sideroxyylon inerme

228 LOGANIACEAE

Strychnos madagascariensis

230 APOCYNACEAE

Hunteria zeylanica

231 ASCLEPIADACEAE
Cynanchum hastifolium
Pentatropis spiralis
Stathmostelma pedunculatum
Strobopetalum bentii
232 RUBIACEAE
Canthium bibracteatum
Catunaregam nilotica
Didymosalpinx norae
Diodia aulacosperma
Gardenia jovis-tonantis
Gardenia ternifolia
Keetia zanzibarica
Kohautia caespitosa
Kraussia kirkii
Kraussia speciosa
Lamprothamnus zanguebaricus
Pentodon pentandrus
Polysphaeria multiflora
Polysphaeria parvifolia
Psychotria punctata
Psychotria riparia
Spermacoce filituba
Tarenna graveolens
Tarenna trichantha
238 COMPOSITAE
Aspilia macrorrhiza
Brachylaena hutchinsii
Eclipta prostrate
Commiphora pteleifolia
Lobelia fervens
245 GOODENIACEAE
Scaveola plumieri
Scaveola taccada
249 BORAGINACEAE
Bourreria nemoralis
Coldenia procumbens
Cordia monoica
Cordia sinensis
Cordia somaliensis
Cordia subcordata
Ehretia bakeri
Ehretia cymosa
Ehretia littoralis
Ehretia petiolaris
Heliotropium albohispidum
Heliotropium spp.
Heliotropium subulatum
250 SOLANACEAE
Datura metel
Solanum goetzei
Solanum hastifolium
Solanum pampaninii
Solanum spp.
251 CONVOLVULACEAE
Cressa cretica
Evolvulus alsinoides
Hewittia sublobata
Hildebrandtia obcordata
258 PEDALIACEAE
Pedalium murex
Sesamum calycimum
259 ACANTHACEAE
Asystasia gangetica
Blepharis maderaspatensis
Ecbolium armplexicaule
Ecbolium striatum
Ecbolium viride
Hygrophilla auriculata
Justicia flava
Justicia stachytarphetoides
Monechma debile
Peristrophe bicalyculata
Ruellia patula
263 VERBENACEAE
Avicennia marina
Clerodendrum cephalanthum
Clerodendrum incisum
Clerodendron myricoides
Lantana viburnoides
Lippia somalensis
Premna resinosa
Premna velutina
Vitex carvalhi
Vitex ferruginea
Vitex mombassae
264 LABIATAE
Ocimum viride

Emilia discifolia
Launaea intybacea
Launaea sarmentosa
Pluchea sordid
Senecio billiodes
Sphaeranthus ukambensis
Vernonia homilantha
Vernonia hildebrandtii

239 GENTIANACEAE

Enicostema axillare

241 PLUMBAGINACEAE

Plumbago stenophylla

243 CAMPANULACEAE

Lightfootia napiformis

244 LOBELLIACEAE

Cyphia glandulifera

Ipomoea fistulosa
Ipomoea lapathifolia
Ipomoea obscura
Jacquemontia tamnifolia
Merremia tridentata
Merremia tridentata
Operculina trupethum

252 SCROPHULARIACEAE

Striga gesnerioides

253 OROBANCHACEAE

Cistanche tubulosa

257 BIGNONIACEAE

Fernandoa magnifica
Markhamia zanzibarica
Tecoma stans

Tinnea aethiopica

266 HYDROCHARITACEAE

Lagarosiphon tenuis
Halophila balfouri

276 POTAMOGETONACEAE

Cymodocea rotundata

280 COMMELINACEAE

Aneilema aequinoctiale
Aneilema petersii

293 LILIIFLORAE

Chlorophytum filipendulum

311 DIOSCOREACEAE

Dioscorea histiflora

314 PALMAE

Hyphaene coriacea

331 CYPERACEAE

Cyperus compressus
Cyperus denudatus
Cyperus grandis
Cyperus haspan
Cyperus sp.
Cyperus tenuispica
Fimbristylis dichotoma
Fimbristylis exilis
Fuirena ciliaris
Mariscus phillipsiae
Mariscus pseudovestitus

Cymbopogon caesius
Dactyloctenium australe
Dactyloctenium ctenioides
Dactyloctenium geminatum
Digitaria argyrotricha
Digitaria milanjiana
Enteropogon sechellensis
Eragrostis caespitosa
Eragrostis ciliaris
Hackelochloa granularis
Halopyrum mucronatum
Heteropogon contortus

Panicum pinifolium
Panicum trichocladum
Paspalum scrobiculatum
Pennisetum polystachyon
Perotis patens
Schizachyrium sanguineum
Schoennefeldia transiens
Sorghum versicolor
Rhynchelytrum repens
Sacciolepis curvata
Schizachyrium sanguineum
Schoenefeldia transiens

Pycreus pumilus
Scirpus confuses

332 GRAMINAE

Aristida adscensionis
Aristida stenostachya
Brachiaria deflexa
Brachiaria leersiodes
Brachiaria leucacrantha
Cenchrus ciliaris
Cenchrus mitis
Chloris mossambicensis
Chloris roxyburgiana
Hyperthelia dissoluta
Lepturus radicans
Lepturus repens
Megastachya mucronata
Oryza longistaminata
Oryza punctata
Panicum astrosanguineum
Panicum coloratum
Panicum deustum
Panicum hippothrix
Panicum infestum
Panicum maximum
Setaria incrassate
Sporobolus kentrophyllus
Urochloa trichopus

406 OPHIOGLOSSACEAE

Ophioglossum costatum
Ophioglossum gomezianum

417 ADIANTACEAE

Pellaea adiantoides

424 THELYPTERIDACEAE

Cyclosorus dentatus

429 POLYPODIACEAE

Platycerium angolense

Id	Species	Family
259	Asystasia gangetica	ACANTHACEAE
259	Blepharis maderaspatensis	ACANTHACEAE
259	Ecbolium armplexicaule	ACANTHACEAE
259	Ecbolium striatum	ACANTHACEAE
259	Ecbolium viride	ACANTHACEAE
259	Hygrophilla auriculata	ACANTHACEAE
259	Justicia flava	ACANTHACEAE
259	Justicia stachytarphetoides	ACANTHACEAE
259	Monechma debile	ACANTHACEAE
259	Peristrophe bicalyculata	ACANTHACEAE
259	Ruellia patula	ACANTHACEAE
417	Pellaea adiantoides	ADIANTACEAE
55	Gisekia Africana	AIZOACEAE
55	Glinus lotoides	AIZOACEAE
55	Trianthema triquetra	AIZOACEAE
55	Zaleya pentandra	AIZOACEAE
63	Achyranthes aspera	AMARANTHACEAE
63	Aerva javanica	AMARANTHACEAE
63	Albizia glaberrima	AMARANTHACEAE
63	Dichrostachyus cinerea	AMARANTHACEAE
63	Neptunia oleracea	AMARANTHACEAE
332	Aerva lanata	AMARANTHACEAE
332	Aerva leucura	AMARANTHACEAE
332	Aerva persica	AMARANTHACEAE
332	Aristida adscensionis	AMARANTHACEAE
332	Aristida stenostachya	AMARANTHACEAE
332	Brachiaria deflexa	AMARANTHACEAE
332	Brachiaria leersiodes	AMARANTHACEAE
332	Brachiaria leucacrantha	AMARANTHACEAE

332	Celosia schweinfurthiana	AMARANTHACEAE
332	Cenchrus ciliaris	AMARANTHACEAE
332	Cenchrus mitis	AMARANTHACEAE
332	Centrostachys aquatic	AMARANTHACEAE
332	Chloris mossambicensis	AMARANTHACEAE
332	Chloris roxyburgiana	AMARANTHACEAE
332	Cyathula coriacea	AMARANTHACEAE
332	Digera muricata	AMARANTHACEAE
332	Psilotrichum sericeum	AMARANTHACEAE
205	Lannea alata	ANACARDIACEAE
205	Lannea schweinfurthii	ANACARDIACEAE
205	Ozoroa obovatum	ANACARDIACEAE
205	Rhus natalensis	ANACARDIACEAE
205	Sorindeia madagascariensis	ANACARDIACEAE
8	Uvaria acuminate	ANNONACEAE
8	Uvaria lucida	ANNONACEAE
230	Hunteria zeylanica	APOCYNACEAE
212	Cussonia zimmermannii	ARALIACEAE
231	Cynanchum hastifolium	ASCLEPIADACEAE
232	Pentatropis spiralis	ASCLEPIADACEAE
233	Stathmostelma pedunculatum	ASCLEPIADACEAE
234	Strobopetalum bentii	ASCLEPIADACEAE
257	Cymbopogon caesius	BIGNONIACEAE
257	Dactyloctenium australe	BIGNONIACEAE
257	Dactyloctenium ctenioides	BIGNONIACEAE
257	Dactyloctenium geminatum	BIGNONIACEAE
257	Digitaria argyrotricha	BIGNONIACEAE
257	Digitaria milanjiana	BIGNONIACEAE
257	Enteropogon sechellensis	BIGNONIACEAE
257	Eragrostis caespitosa	BIGNONIACEAE
257	Eragrostis ciliaris	BIGNONIACEAE

257	Fernandoa magnifica	BIGNONIACEAE
257	Hackelochloa granularis	BIGNONIACEAE
257	Halopyrum mucronatum	BIGNONIACEAE
257	Hermannia exappendiculata	BIGNONIACEAE
257	Heteropogon contortus	BIGNONIACEAE
257	Hyperthelia dissoluta	BIGNONIACEAE
257	Lepturus radicans	BIGNONIACEAE
257	Lepturus repens	BIGNONIACEAE
257	Markhamia zanzibarica	BIGNONIACEAE
257	Megastachya mucronata	BIGNONIACEAE
257	Melhania taylori	BIGNONIACEAE
257	Melhania velutina	BIGNONIACEAE
257	Oryza longistaminata	BIGNONIACEAE
257	Oryza punctata	BIGNONIACEAE
257	Panicum astrosanguineum	BIGNONIACEAE
257	Panicum coloratum	BIGNONIACEAE
257	Panicum deustum	BIGNONIACEAE
257	Panicum hippothrix	BIGNONIACEAE
257	Panicum infestum	BIGNONIACEAE
257	Panicum maximum	BIGNONIACEAE
257	Sterculia Africana	BIGNONIACEAE
257	Tecoma stans	BIGNONIACEAE
257	Waltheria indica	BIGNONIACEAE
249	Bourreria nemoralis	BORAGINACEAE
249	Coldenia procumbens	BORAGINACEAE
249	Cordia monoica	BORAGINACEAE
249	Cordia sinensis	BORAGINACEAE
249	Cordia somaliensis	BORAGINACEAE
249	Cordia subcordata	BORAGINACEAE
249	Ehretia bakeri	BORAGINACEAE
249	Ehretia cymosa	BORAGINACEAE

249	Ehretia littoralis	BORAGINACEAE
249	Ehretia petiolaris	BORAGINACEAE
249	Heliotropium albohispidum	BORAGINACEAE
249	Heliotropium spp.	BORAGINACEAE
249	Heliotropium subulatum	BORAGINACEAE
196	Commiphora africana	BURSERRACEAE
196	Commiphora boiviniana	BURSERRACEAE
196	Commiphora pteleifolia	BURSERRACEAE
196	Lobelia fervens	BURSERRACEAE
154	Buxus obtusiflolia	BUXACEAE
146	Cassia abbreviata	CAESALPINIACEAE
146	Chamaecrista mimosoides	CAESALPINIACEAE
146	Senna siamea	CAESALPINIACEAE
146	Tamarindus indica	CAESALPINIACEAE
243	Lightfootia napiformis	CAMPANULACEAE
36	Boscia angustifolia	CAPPARACEAE
36	Boscia coriacea	CAPPARACEAE
36	Cadaba farinosa	CAPPARACEAE
36	Capparis viminea	CAPPARACEAE
36	Cladostemon kirkii	CAPPARACEAE
36	Maerua angolensis	CAPPARACEAE
36	Maerua calantha	CAPPARACEAE
36	Maerua oblongifolia	CAPPARACEAE
36	Maerua triphylla	CAPPARACEAE
36	Thylachium africanum	CAPPARACEAE
36	Thylachium thomasii	CAPPARACEAE
53	Polycarpaea grahamii	CARYOPHYLLACEAE
53	Polycarpaea spicata	CARYOPHYLLACEAE
173	Elaeodendron schweinfurthianum	CELASTRACEAE
174	Hippocratea Africana	CELASTRACEAE
175	Hippocratea crenata	CELASTRACEAE

176	Maytenus mossambicensis	CELASTRACEAE
177	Maytenus undata	CELASTRACEAE
178	Mystroxylon aethiopicum	CELASTRACEAE
179	Salacia madagascariensis	CELASTRACEAE
61	Arthrocnemum indicum	CHENOPODIACEAE
62	Salicornia pachystachya	CHENOPODIACEAE
121	Combretum constrictum	COMBRETACEAE
121	Combretum illairii	COMBRETACEAE
121	Lumnitzera racemosa	COMBRETACEAE
121	Terminalia prunoides	COMBRETACEAE
280	Aneilema aequinoctiale	COMMELINACEAE
280	Aneilema petersii	COMMELINACEAE
238	Aspilia macrorrhiza	COMPOSITAE
238	Brachylaena hutchinsii	COMPOSITAE
238	Eclipta prostrate	COMPOSITAE
238	Emilia discifolia	COMPOSITAE
238	Launaea intybacea	COMPOSITAE
238	Launaea sarmentosa	COMPOSITAE
238	Pluchea sordid	COMPOSITAE
238	Senecio billiodes	COMPOSITAE
238	Sphaeranthus ukambensis	COMPOSITAE
238	Vernonia hildebrandtii	COMPOSITAE
238	Vernonia homilantha	COMPOSITAE
206	Rourea coccinea	CONNARACEAE
206	Rourea orentalis	CONNARACEAE
251	Cressa cretica	CONVOLVULACEAE
251	Evolvulus alsinoides	CONVOLVULACEAE
251	Hewittia sublobata	CONVOLVULACEAE
251	Hildebrandtia obcordata	CONVOLVULACEAE
251	Ipomoea fistulosa	CONVOLVULACEAE
251	Ipomoea lapathifolia	CONVOLVULACEAE

251	Ipomoea obscura	CONVOLVULACEAE
251	Jacquemontia tamnifolia	CONVOLVULACEAE
251	Merremia tridentata	CONVOLVULACEAE
251	Merremia tridentata	CONVOLVULACEAE
251	Operculina trupethum	CONVOLVULACEAE
103	Peponium vogelli	CUCURBITACEAE
331	Cyperus compressus	CYPERACEAE
331	Cyperus denudatus	CYPERACEAE
331	Cyperus grandis	CYPERACEAE
331	Cyperus haspan	CYPERACEAE
331	Cyperus sp.	CYPERACEAE
331	Cyperus tenuispica	CYPERACEAE
331	Fimbristylis dichotoma	CYPERACEAE
331	Fimbristylis exilis	CYPERACEAE
331	Fuirena ciliaris	CYPERACEAE
331	Mariscus phillipsiae	CYPERACEAE
331	Mariscus pseudovestitus	CYPERACEAE
331	Pycreus pumilus	CYPERACEAE
331	Scirpus confuses	CYPERACEAE
311	Dioscorea histiflora	DIOSCOREACEAE
221	Diospyros consolatae	EBENACEAE
221	Diospyros mespiliformis	EBENACEAE
221	Diospyros natalensis	EBENACEAE
221	Diospyros spp.	EBENACEAE
221	Diospyros squarrosa	EBENACEAE
135	Erythroxylon emarginatum	ERYTHROXYLACEAE
135	Hugonia castaneifolia	ERYTHROXYLACEAE
136	Acalypha indica	EUPHOBIACEAE
136	Antidesma venosum	EUPHOBIACEAE
136	Bridelia scleroneura	EUPHOBIACEAE
136	Caperonia fistulosa	EUPHOBIACEAE

136	Croton pseudoputchellus	EUPHOBIACEAE
136	Croton talaeporos	EUPHOBIACEAE
136	Drypetes natalensis	EUPHOBIACEAE
136	Euphorbia cuneata	EUPHOBIACEAE
136	Euphorbia prostrata	EUPHOBIACEAE
136	Excoecaria bussei	EUPHOBIACEAE
136	Fluggea virosa	EUPHOBIACEAE
136	Jatropha spicata	EUPHOBIACEAE
136	Oldfieldia somalensis	EUPHOBIACEAE
136	Phyllanthus reticulata	EUPHOBIACEAE
136	Suregada zansibarensis	EUPHOBIACEAE
93	Grandidiera boivinii	FLACOURTIACEAE
239	Enicostema axillare	GENTIANACEAE
245	Scaveola plumieri	GOODENIACEAE
245	Scaveola taccada	GOODENIACEAE
314	Panicum pinifolium	GRAMINAE
314	Panicum trichocladum	GRAMINAE
314	Paspalum scrobiculatum	GRAMINAE
314	Pennisetum polystachyon	GRAMINAE
314	Perotis patens	GRAMINAE
314	Rhynchelytrum repens	GRAMINAE
314	Sacciolepis curvata	GRAMINAE
314	Schizachyrium sanguineum	GRAMINAE
314	Schizachyrium sanguineum	GRAMINAE
314	Schoenefeldia transiens	GRAMINAE
314	Schoennefeldia transiens	GRAMINAE
314	Setaria incrassata	GRAMINAE
314	Sorghum versicolor	GRAMINAE
314	Sporobolus kentrophyllus	GRAMINAE
314	Urochloa trichopus	GRAMINAE
126	Garcinia livingstonei	GUTTIFERAE

266	Halophila balfouri	HYDROCHARITACEAE
266	Lagarosiphon tenuis	HYDROCHARITACEAE
179	Pyrenancantha malvifolia	ICACINACEAE
265	Ocimum viride	LABIATAE
265	Tinnea aethiopica	LABIATAE
11	Cassytha filiformis	LAURACEAE
293	Chlorophytum filipendulum	LILIIFLORAE
244	Cyphia glandulifera	LOBELLIACEAE
228	Strychnos madagascariensis	LOGANIACEAE
185	Odontella kelleri	LORANTHACEAE
185	Odontella spp.	LORANTHACEAE
185	Oliverella hildebrandtii	LORANTHACEAE
185	Plicosepalus curviflorus	LORANTHACEAE
185	Spragueanella rhamnifolia	LORANTHACEAE
185	Tapinanthus sansibarensis	LORANTHACEAE
133	Acridocarpus zanzibaricus	MALPHIGIACEAE
132	Abutilon hirtum	MALVACEAE
132	Hibiscus cannabinus	MALVACEAE
132	Hibiscus micranthus	MALVACEAE
132	Pavonia mollissima	MALVACEAE
132	Pavonia zeylanica	MALVACEAE
132	Sida acuta	MALVACEAE
132	Thespesia danis	MALVACEAE
132	Thespesia populnea	MALVACEAE
197	Azadirachta indica	MELIACEAE
197	Trichilia emetica	MELIACEAE
197	Turraea nilotica	MELIACEAE
197	Xylocarpus granatum	MELIACEAE
197	Xylocarpus moluccensis	MELIACEAE
147	Acacia nilotica	MIMOSACEAE
147	Acacia Senegal	MIMOSACEAE

147	Commiphora schimperi	MIMOSACEAE
147	Commiphora trothae	MIMOSACEAE
167	Ficus changuensis	MORACEAE
167	Milicia excels	MORACEAE
114	Ochna mossambicensis	OCHNACEAE
114	Ochna ovate	OCHNACEAE
114	Ochna thomasiana	OCHNACEAE
182	Ximenia Americana	OLACACEAE
406	Ophioglossum costatum	OPHIOGLOSSACEAE
406	Ophioglossum gomezianum	OPHIOGLOSSACEAE
253	Cistanche tubulosa	OROBANCHACEAE
314	Hyphaene coriacea	PALMAE
148	Abrus precatorius	PAPILIONACEAE
148	Aeschynomene uniflora	PAPILIONACEAE
148	Alysicarpus glumaceus	PAPILIONACEAE
148	Anglocalyx braunnii	PAPILIONACEAE
148	Canavalia rosea	PAPILIONACEAE
148	Craibia brevicaudata	PAPILIONACEAE
148	Crotalaria boranica	PAPILIONACEAE
148	Crotalaria distantiflora	PAPILIONACEAE
148	Crotalaria emarginata	PAPILIONACEAE
148	Crotalaria laburnifolia	PAPILIONACEAE
148	Crotalaria malindiensis	PAPILIONACEAE
148	Crotalaria retusa	PAPILIONACEAE
148	Crotalaria ukambensis	PAPILIONACEAE
148	Dalbergia melanoxylon	PAPILIONACEAE
148	Eriosema glomeratum	PAPILIONACEAE
148	Eriosema parviflorum	PAPILIONACEAE
148	Erythrina saccleuxii	PAPILIONACEAE
148	Indigofera brachynema	PAPILIONACEAE
148	Indigofera cliffordiana	PAPILIONACEAE

148	Indigofera microcarpa	PAPILIONACEAE
148	Indigofera schimperi	PAPILIONACEAE
148	Indigofera tanganyikensis	PAPILIONACEAE
148	Indigofera tinctoria	PAPILIONACEAE
148	Indigofera trita	PAPILIONACEAE
148	Indigofera wituensis	PAPILIONACEAE
148	Lonchocarpus bussei	PAPILIONACEAE
148	Ormocarpum kirkii	PAPILIONACEAE
148	Rhynchosia hirta	PAPILIONACEAE
148	Rhynchosia velutina	PAPILIONACEAE
148	Sesbania bispinosa	PAPILIONACEAE
148	Sesbania keniensis	PAPILIONACEAE
148	Sophora tomentosa	PAPILIONACEAE
148	Tephrosia nubica	PAPILIONACEAE
148	Tephrosia pumila	PAPILIONACEAE
148	Tephrosia purpurea	PAPILIONACEAE
148	Tephrosia villosa	PAPILIONACEAE
148	Vigna membranacea	PAPILIONACEAE
148	Vigna unguiculata	PAPILIONACEAE
101	Adenia venenata	PASSIFLORACEAE
101	Basananthe lanceolata	PASSIFLORACEAE
101	Schlechterina mitostemmatoides	PASSIFLORACEAE
258	Pedalium murex	PEDALIACEAE
258	Sesamum calycimum	PEDALIACEAE
241	Plumbago stenophylla	PLUMBAGINACEAE
57	Oxygonum atriplicifolium	POLYGONACEAE
57	Oxygonum salicifolium	POLYGONACEAE
429	Platycerium angolense	POLYPODIACEAE
56	Portulaca pilosa	PORTLACACEAE
56	Talinum portulacifolium	PORTLACACEAE
276	Cymodocea rotundata	POTAMOGETONACEAE

190	Lasiodiscus mildbraedii	RHAMNACEAE
190	Ziziphus mauritiana	RHAMNACEAE
190	Ziziphus mucronata	RHAMNACEAE
122	Bruguiera gymnorrhiza	RHIZOPHORACEAE
123	Cassipourea euryoides	RHIZOPHORACEAE
124	Ceriops tagal	RHIZOPHORACEAE
125	Rhizophora mucronata	RHIZOPHORACEAE
232	Canthium bibracteatum	RUBIACEAE
232	Catunaregam nilotica	RUBIACEAE
232	Didymosalpinx norae	RUBIACEAE
232	Diodia aulacosperma	RUBIACEAE
232	Gardenia jovis-tonantis	RUBIACEAE
232	Gardenia ternifolia	RUBIACEAE
232	Keetia zanzibarica	RUBIACEAE
232	Kohautia caespitosa	RUBIACEAE
232	Kraussia kirkii	RUBIACEAE
232	Kraussia speciosa	RUBIACEAE
232	Lamprothamnus zanguebaricus	RUBIACEAE
232	Pentodon pentandrus	RUBIACEAE
232	Polysphaeria multiflora	RUBIACEAE
232	Polysphaeria parvifolia	RUBIACEAE
232	Psychotria punctata	RUBIACEAE
232	Psychotria riparia	RUBIACEAE
232	Spermacoce filituba	RUBIACEAE
232	Tarenna graveolens	RUBIACEAE
232	Tarenna trichantha	RUBIACEAE
194	Zanthoxylum chalybeum	RUTACEAE
156	Populus ilicifolia	SALICACEAE
180	Azima tetracantha	SALVADORACEAE
180	Dobera loranthifolia	SALVADORACEAE
180	Salvadora persica.	SALVADORACEAE

198	Allophylus rubifolius	SAPINDACEAE
198	Cardiospermum halicacabum	SAPINDACEAE
198	Haplocoelum foliolosum	SAPINDACEAE
198	Haplocoelum inoploeum	SAPINDACEAE
198	Lecaniodiscus fraxinifolius	SAPINDACEAE
198	Lepisanthes senegalensis	SAPINDACEAE
198	Majidea zanguebarica	SAPINDACEAE
198	Paulinia pinnata	SAPINDACEAE
222	Euclea schimperi	SAPOTACEAE
222	Inhambanella henriquerii	SAPOTACEAE
222	Manilkara sulcata	SAPOTACEAE
222	Pachystela verticillata	SAPOTACEAE
222	Sideroxyylon inerme	SAPOTACEAE
252	Striga gesnerioides	SCROPHULARIACEAE
195	Harrisonia abyssinica	SIMAROUBACEAE
250	Datura metel	SOLANACEAE
250	Solanum goetzei	SOLANACEAE
250	Solanum hastifolium	SOLANACEAE
250	Solanum pampaninii	SOLANACEAE
250	Solanum spp.	SOLANACEAE
130	Cola clavata	STERCULIACEAE
130	Dombeya praetermissa	STERCULIACEAE
424	Cyclosorus dentatus	THELYPTERIDACEAE
81	Synaptolepis kirkii	THYMELAECEAE
128	Grewia plagiophylla	TILIACEAE
128	Grewia stuhlmannii	TILIACEAE
128	Grewia vaughanii	TILIACEAE
47	Vahlia dichotoma	VAHLIACEAE
263	Avicennia marina	VERBENACEAE
263	Clerodendron myricoides	VERBENACEAE
263	Clerodendrum cephalanthum	VERBENACEAE

263	Clerodendrum incisum	VERBENACEAE
263	Lantana viburnoides	VERBENACEAE
263	Lippia somalensis	VERBENACEAE
263	Premna resinosa	VERBENACEAE
263	Premna velutina	VERBENACEAE
263	Vitex carvalhi	VERBENACEAE
263	Vitex ferruginea	VERBENACEAE
263	Vitex mombassae	VERBENACEAE
40	Hybanthus densifolius	VIOLACEAE
40	Hybanthus enneaspermus	VIOLACEAE
40	Rinorea squamosa	VIOLACEAE
193	Ampelocissus Africana	VITACEAE
193	Cissus integrifolia	VITACEAE
193	Cissus rotundifolia	VITACEAE
193	Rhoicissus revoilii	VITACEAE
66	Tribulus terrestris	ZYGOPHYLLACEAE