ASSESSMENT OF WOODY PLANTS SPECIES DIVERSITY IN RUSINGA ISLAND, HOMA BAY COUNTY, KENYA

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UNIVERSITY OF NAIROBI

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This thesis is my original work and has not been submitted for award of a degree in any other University.

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DEDICATION

I dedicate this thesis to my parents Augastino Nyaga and Vegelina Karimi, you are my source of encouragement and inspiration throughout my life. May God bless you and give you a long life.

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ACRONYMS AND ABBREVIATIONS

ANOVA- Analysis of Variance

CBD -Convention on Biological Diversity

FAO- Food and Agriculture Organization

FGD-Focus Group Discussion

GPS-Global Positioning System

IUCN- International Union for Conservation of Nature

KFS- Kenya Forest Service

KII-Key Informant Interviews

LEK-Local Ecological Knowledge

NGOs-Non-Governmental Organizations

TEK-Traditional Ecological Knowledge

UNCCD- United Nations Convention to Combat Desertification

ABSTRACT

Land degradation is a major environmental problem as manifested in global decline in woody vegetation and loss of biodiversity. Understanding the dynamics of plant communities is imperative in developing appropriate conservation and management plans for sustainable development. This requires analysis of the plant species composition, diversity, density and cover as a prerequisite for planning and sustainable management of ecosystems for sustainable development. A random sampling design was used to select 150 households from six sub-locations found in Rusinga Island. Household interviews were conducted with the use of a semi-structured questionnaire complemented by four (4) Focus Group Discussions (FGDs) and thirty (30) Key Informant Interviews (KIIs). Ecological data were collected using purposive sampling technique where three hills (Ligongo, Kabade and Wanyama) were selected as reference points to capture the variations in land use gradient from the lowlands through to the hilltops. The slopes of the hills were demarcated into three study zones: lower, middle and upper zone differentiated by the slope gradient and land use. Line transect in combination with sampling plot methods were used during data collection. This involved laying down four-line transects on each hill following the four compass directions, running from the top of the hill to the shores of the lake and cutting across the three zones. Trees were sampled within plots measuring 20 m x20 m ($400m^2$) placed at an interval of 200m, while shrubs and lianas were sampled in sub-plots of 10m by 10m nested in main plots in each of the three study zones along the predetermined line transects. The cover of woody plant species on the three hills at the three different study zones was determined using a line intercept method where a 20m measuring tape was systematically placed along the predetermined transect at an interval of 200m. Any woody plants species intercepted by the tape were identified and intercept distance recorded for determination of cover. The collected data on Shannon's evenness and diversity index, species richness, number of individuals, density, frequency and cover of woody plants were subjected to one-way analysis of variance (ANOVA) to determine the differences among the three study zones.

Results from household interviews show that most (86%) of the respondents had observed changes in vegetation composition and abundance in the study area. The changes were attributed to deforestation, high human population, overgrazing, inadequate rainfall, and soil erosion. The observed changes were reported in the forests/hills (68%), in the entire Island (15.3%) and in the homesteads (2.7 %). The community proposed tree planting, protection of existing trees, use of alternative sources of fuel, increased awareness creation on environmental conservation and controlled livestock grazing as the best strategies to reduce vegetation degradation.

In total, 63 woody plant species from 51 genera and 32 plant families were encountered in the study area, 42 (66.7%) being trees, 20 (31.7%) shrubs and 1(1.6%) liana. The upper zones had significantly higher woody species diversity, species richness, and abundance than the middle and lower zones. The lower zones of the hills had lower plant species diversity (1.87) compared to the middle zones (2.23) and upper zones (2.60). This was attributed to the various activities carried out in the lower zones particularly clearing of the woodland to give way for crop production and settlements.

A statistically significant difference was observed in both the density of trees and shrubs ($P<0.001$) among the three study zones. However, tree species recorded the lowest density in comparison to shrubs. The dominance of shrubs was attributed to intensive and selective logging of trees for different uses. Majority of the people in Rusinga Island are aware of the decline in woody vegetation resources in their area and the possible driving factors affecting the vegetation dynamics. For woody plant species to be effectively conserved and managed, the local people must be actively involved in the management and rehabilitation efforts. The lower species diversity, abundance and species richness in the lowlands and around settlements calls for promotion of agroforestry practices through planting of multipurpose tree species for enhanced ecosystem services. In addition, awareness creation on the consequences of deforestation and the significance of environmental conservation is imperative for sustainable environmental management.

Key words: Woody plant species; Local perceptions; Species diversity; Shannon’s diversity index; Rusinga Island

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Plant diversity is a fundamental element in the biosphere and reinforces societal development in the whole world. Plants cover nearly all the terrestrial ecosystems of the world with exemptions of regions covered with ice and in very arid areas (Sharrock et al., 2014). Despite worldwide progress and growing advancement in horticulture, agriculture, and forestry, indigenous plants are still a source of various goods and services for subsistence and income. Around the World, many people still depend on wild plant resources for their livelihoods as a source of fuel wood, food, building materials, medicine or financial income and lack of those resources poses a serious threat to those needs (Hosseinzadeh et al., 2016). Woody plant species (trees, shrubs or lianas), which are normally found in ecosystems throughout the year (Qian, 2013) provide vital ecosystem services such as wildlife habitats, recreation, carbon storage, prevention of soil erosion, and timber products (DeFries, 2012). More importantly, the rural communities rely on woody plant species for shade, sleeping mats and beds, firewood, medicine, food and forage (Kwaza et al., 2017). In developing countries, over 2 billion people depend on woody vegetation for firewood, which is the key source of energy supply (FAO, 2010). Out of the total primary energy consumed in the whole world, more than 14% of the energy is provided by fuel wood and charcoal (Oduor, 2012). Over 90% of the households in rural areas in Kenya use fuel wood either as charcoal or firewood, with charcoal being the main source of fuel energy in many urban households, and firewood meeting over 93% of rural household’s energy needs (Oduor, 2012). In small-scale industries, fuel wood forms an important source of energy for fish smoking, bakeries, brick making, tea drying, and tobacco curing, amongst other uses (Theuri, 2002). Despite the immense importance of the World’s flora, plant species are under severe threats globally because of habitats conversion into other forms of land use, intentional or accidental introduction of invasive species, overexploitation, climate change, and pollution. Woody plant species are threatened due to the increased demand for more grazing and farmlands and due to increasing fuel wood gap leading to more overexploitation of the remaining stock, hence woody plant species degradation (Gojamme and Tanto, 2016).

In Africa, these threats to biodiversity are not only reported on the mainland but also the islands owing to the rapidly increasing human populace (IUCN,1990). Islands of the world cover over 5.3 % of the land area. Islands have unique ecosystems and their biota is extremely sensitive to extinctions (Jeffries, 1997). About 64% of the extinctions recorded worldwide are experienced on the islands and these losses have aesthetic, ethical and negative economic impacts (Lewis et al., 2013). Despite their rich plant diversity, land degradation and inappropriate conservation measures are major threats to terrestrial island species diversity (Mulongoy et al., 2006). Land degradation indicates a decline in the functions of different ecosystems and a reduced capacity to produce and therefore leads to loss of species at global, regional and local scales through forest fires, urban development, recreation, agriculture, tree logging and road building (Mebrat and Gashaw, 2013). Land degradation is caused by both climatic and human factors like; overgrazing, drought and desiccation, unsustainable land-tenure rights and other numerous economic and social processes (Mganga, 2009). However, land degradation through anthropogenic activities is considered the leading cause of risk for 83% of endangered plant species (Turner, 1996). The impacts of land degradation include; wind and water erosion, reduction of vegetation cover, salinization and loss of biological & economic productivity (Mganga, 2009). Land/forest degradation leads to alterations of species composition and diversity and eventually affects biodiversity (Omoro et al., 2010). Sustainable land rehabilitation requires site-specific and reliable data to guide interventions, however, studies on the floristic composition, diversity and distribution, particularly the woody plant species of Rusinga Island are scanty, therefore motivating the current study. Rusinga Island is the second-largest island after Ukerewe Island of Tanzania in Lake Victoria ecosystem (Opiyo et al., 2007). Rusinga Island is not only a biodiversity hotspot but also an ancient historic area with numerous archaeological sites that have given the World fossils dating back millions of years (Tryon et al., 2012). However, the area has been experiencing a downward trend in its ecosystems (Ketelaars, 2015). The availability of adequate data on the diversity and composition of woody plants is vital for better development and implementation of community conservation strategies and better understanding of the forest community structures (Malik and Bhatt, 2015).

1.2 STATEMENT OF THE PROBLEM

A decline in woody vegetation is a major environmental problem in Kenya. The trend is attributed to several factors, which include; loss of soil structure and fertility, invasive species, water and wind erosion, land-use changes, salinization, overexploitation and other processes that result in the decline of the diversity and density of vegetation in the long-term (Sambou et al., 2016). A decline in woody plant species affects the services offered like construction materials and firewood causing large welfare losses to the most vulnerable individuals in the community (Sinare and Gorden, 2015). The changes in vegetation affect household livelihoods since most of the plants are useful as medicine, food, fodder and firewood (Sambou et al., 2016). Some anthropogenic activities like clearing of forests for grazing and agricultural activities combined with some climatic factors like changes in precipitation cause the decrease of the cover of woody plant species and all these results in increased soil erosion and reduction in biodiversity. As observed by Jackson et al. (2002), changes in ecosystem biomass result in altered carbon cycles worldwide. In particular, human population increase is triggering the clearing of more woody plants for poles for construction of houses and to make way for cropping systems and these losses of woody plant species change the ecology of most ecosystems thus upsetting the goods and services offered by those ecosystems.

Some attempts in different parts of Kenya have been made to study plant species diversity (Otuoma and Odera, 2008; Bagine, 1998) but no such attempts had been reported in Rusinga Island despite its significance to the local communities. A few studies that had been conducted in Rusinga Island concentrated on the prevalence and prevention of Malaria (Olanga et al., 2015; Homan et al., 2015, Weckenbrock and Oldesloe, 2004; Ketelaars, 2015). Additionally, Osoro et al. (2016) determined the contamination of water with sediments and pesticides with no attention given to the ecological data of the Island despite reports by residents that there is increased land degradation, loss of woody plants and the general change in vegetation cover (Mureithi et al., 2018)

1.3 JUSTIFICATION OF THE STUDY

Woody plants form the principal components of forests and many other ecosystems on the planet. Being among the largest and longest-living organisms, they support an immense share of the Earth's terrestrial biodiversity, providing food, habitat for innumerable microorganisms, epiphytes and invertebrate and vertebrate species. Therefore, woody plant species have inestimable scientific, economic, social, cultural and aesthetic value. Despite their importance, woody plants undergo many stresses, which have many causes that might ultimately lead to their decline. Typically, one or more primary stresses cause deterioration of plant health, followed by secondary pathogens and/or insects that further decline or destroy plants. Determination of the causes of the decline requires careful examination of plants and growing sites, as well as the knowledge of site history. A wider range of possible causes of the decline in woody plant material should be considered during evaluation. Understanding of the dynamics of the compositions of species in plant communities is important to inform on appropriate conservation plans and for sustainable development. Rusinga Island is a historical and priority area, which is experiencing a downward trend in its ecosystems due to increased land degradation and deforestation. In addition, there are limited previous studies in terms of the floristic composition of woody plant species on this area and there is an alarming loss of woody plants especially the indigenous species. To ensure effective planning and management of ecosystems for sustainable development, detailed and reliable data on plant resources is of utmost importance. Evaluations such as the diversity, composition, density and cover of woody plant species are vital in the comprehension of the level of plant diversity in an ecosystem. Information on the structure and composition of the flora of forest ecosystems is valuable in recognition of essential components of plant diversity, safeguarding of vulnerable and economically significant plant species and in the monitoring and evaluation of the status of vegetation over time. Woody vegetation has high economic and ecological importance like provision of firewood, timber, medicinal value and most importantly maintaining biodiversity and landscape. Therefore, assessment of woody plant species diversity on the Island is vital to inform sustainable utilization of woody plant resources.

Understanding the perceptions of the local communities on the status and the approaches, they use to manage the natural resources helps to increase the transparency and effectiveness of natural resource conservation. Thus, any program intending to develop sustainable conservation measures or policies, regulations, rules, and strategies needs to consider the opinions of the local people. In addition to generating data on floristic diversity, composition, cover and density, of woody plants in Rusinga Island, the current study's expectations were to contribute to raising public awareness on environmental conservation thus avoiding or minimizing environmental degradation. Eventually, the findings were anticipated to be used as a baseline in providing information on the status of woody vegetation in the area to policy-makers, NGOs and development agents.

1.4 OBJECTIVES

1.4.1 Broad objective

The broad objective of this study was to contribute towards sustainable utilization and effective conservation of woody plant resources for better environment and livelihoods in Rusinga Island.

1.4.2 Specific objectives

The specific objectives of this study were to:

1. To assess the perceptions of the local community on the changes in vegetation composition and abundance in Rusinga Island
2. To determine the diversity, composition, density and cover of woody plants species in Rusinga Island

1.5 RESEARCH QUESTIONS

1. How does the local community perceive the changes in vegetation composition and abundance in Rusinga Island?
2. What is the diversity, composition, density and cover of woody plants species in Rusinga Island?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. Local knowledge on the changes in vegetation composition and abundance.

Traditional ecological knowledge is a cumulative body of knowledge about the relationships of living things (including people) with each other and their environment, and it is passed across generations through cultural transmission (Berkes, 1999). Traditional ecological knowledge (TEK) includes knowledge, practices, and beliefs that are more-or-less integrated with one another. It is dynamic and evolves as people build on their experiences and observations, experiment, learn from others, and adapt to changing environmental conditions over time. TEK is place-based and geographically specific, and is most often found among societies that have engaged in natural resource use in a place over a long period, such as indigenous people (Berkes, 1999). However, new knowledge is created all the time, and indigenous people are not the only ones who have ecological knowledge of value. There is a more recent local ecological knowledge (LEK) which is the knowledge, practices, and beliefs regarding ecological relationships that are gained through extensive personal observation of and interaction with local ecosystems, and shared among local resource users (Charnley et al., 2007). Local ecological knowledge may eventually become TEK.

Use of indigenous knowledge is a quick and reliable method of acquiring information without resorting to sophisticated technology (Sulieman et al., 2012). A further advantage is the availability of information on a single species basis, which can be directly used for local resource management and re-introduction of threatened species (Wezel, 2004). Furthermore, supplementing scientific data with local and traditional knowledge can broaden the information base needed for informed decision-making regarding ecosystem and sustainable resource management (Yli-Pelkonen and Kohl, 2005). Lykke et al. (1999) stated that there is an increased use of local information as a basis for land management strategies because of its value and creditability concerning environmental issues. Local societies harbour important information on valuable plants and vegetation dynamics that is fundamental for management strategies aimed at sustainable use and conservation of natural vegetation (Lykke, 2000). This is especially the case when other historical ecological information is unavailable.

The local people have in-depth information on the kinds of vegetation in their areas and their values (Seely and Wöhl, 2004) and this knowledge helps policymakers to design policies that are suitable for land management (Mapinduzi et al., 2003). The local communities have intermingled with their environment since time immemorial and they have established different methods of managing their ecosystems by using their indigenous knowledge and approaches (Berkes et al., 2000). This knowledge is essential in natural resource management and conservation (Ticktin and Johns, 2002). To ensure successful management of natural resources, it is important to combine both the traditional ecological knowledge and the recent conservation strategies (Berkes and Turner, 2006).

In the recent past, technical advances have shown that the entire world is undergoing rapid ecological changes and the most pronounced and obvious changes are caused by human land use (Wasonga et al., 2011). A study carried out by Wasonga et al. (2011) in Kenya to assess the socio-ecological change dynamics using local knowledge reported that the respondents perceived that there were changes in vegetation characteristics since the plant diversity and cover generally declined. The reasons behind the changes were reported to be decrease in rain-days, overgrazing and felling of trees for building and fencing in that order as the leading causes of the decline in plant species diversity. The general decline in vegetation cover was however attributed to land clearing for settlement and cultivation, decline in rain-days and frequent droughts, overgrazing and cutting of trees for building and fencing in that order.

In a study to examine the dynamics and the current state of vegetation and its importance to the Groundnut Basin rural people in Senegal, Sambou et al. (2016), found that the older people who were interviewed reported that vegetation had changed since 1993 in composition and abundance. Majority (86%) of the mentioned trees were perceived by the respondents as rare species while 14% were abundant species. In the study, the influences of changes in vegetation were identified and they included overexploitation, land-use changes, climatic changes and soil salinization. Angassa et al. (2012) conducted a study in Kenya, Botswana, and Mali to assess the local community's knowledge on the native vegetation found in their landscapes and they found that the local people had comprehensive information on the indicators that are useful in assessing the condition of native vegetation. The indicators mentioned included soil type, grazing pressure and topographic variation.

Maunguja (2016) conducted a study in the Kenyan Coast on the knowledge, uses and conservation status of medicinal plants and he reported that there were seven types of threats to the plants and they included deforestation, charcoal production, climate change, limited livelihood sources, drought, commercialization of forest products and clearing of land for cultivation. In his study, he reported that the respondents proposed domestication of wild medicinal plants, regulation on the use of the wild plants, monitoring by government ministry and agencies and formation of conservation groups as the most appropriate and effective measures for the conservation of wild herbal plants. Tabuti (2012), in Uganda while assessing the management and the status of some important woody plants revealed that within the community seventeen woody plant species were the most valued and all these species were multipurpose and they had 25 diverse uses altogether. His study also indicated that the leading factors to the shortage of plant species were pests, over-harvesting and droughts while some of the success contributing factors were natural regeneration, planting, faster maturity, easy to manage, resistance to drought and availability of seedlings.

2.2 Biodiversity, trends in plant species diversity and factors affecting woody plant species diversity

Biodiversity is a comprehensive umbrella term for the extent of nature's variety or variation within the natural system; both in number and frequency. It is often understood in terms of the wide variety of plants, animals and microorganisms, the genes they contain and the ecosystem they form (Rawat and Agarwal, 2015). There are several definitions of biodiversity, but the one adopted by the Convention on Biological Diversity (CBD) is widely used (Gebreselasse, 2011). The Convention on Biological Diversity defines biodiversity as "the variety of life on earth, including plants, animals, and microorganisms, as well as the ecosystems which they are part of." Biodiversity is therefore considered at 3 major levels: genetic, species and ecosystem level (Mutia, 2009). Where genetic diversity is the variety of genetic information contained in all of the individual plants, animals and microorganisms occurring within population of species, ecosystem diversity relates to the variety of habitats, biotic communities and ecological processes in the biosphere (Mutia, 2009). Species diversity is the variety of species or the living organisms. Species diversity is usually measured in terms of species evenness, which is the distribution of individuals among species, and species richness, which is the number of species present in an area (Hengeveld, 1996). Thus, species richness and species diversity are related but they are different concepts even though some ecologists use them interchangeably. Numerous biotic and abiotic factors like seasonality and annual precipitation are in control of species diversity (Gillespie, 2000).

Plant diversity is an essential component of the biosphere and underpins societal development worldwide (Sharrock et al., 2014). In particular, the woody plant resources serve the function of supplying the basic needs, savings for cash resources and providing safety-net during hard times where basic needs include goods such as fuel wood, medicine and construction materials among others (Shackleton et al., 2007). The function of woody plant species like the provision of food, energy, shelter and medicine reduces the costs of living to the poor rural people and the costs the governments would have incurred in providing these services and hence cash savings (Danda, 2014). Despite their importance, most plant species are facing threats such as deforestation, invasive species, climate change, pollution, overexploitation, and unsustainable use (Mebrat and Gashaw, 2013). In most of the developing countries increase in poverty and population density have been contributed by the loss of woodlands since most of the local people are engaging in small scale farming and harvesting of wood illegally thus degrading the woodlands (Muchayi et al., 2017).

Information on the diversity of plants is a vital tool in the management and conservation of tropical plants (Kadavul and Parthasarathy, 1999). Some ecologists have made their contributions on ecological diversity (Wassie et al., 2010; Erenso et al., 2014; Gotelli and Colwell, 2011) and found varying results. Gojamme and Tanto (2016) conducted a study in Wotagisho forest, Ethiopia to determine the diversity and composition of woody plant species and they recorded a total of 51 plant species from 47 genera and 31 plant families. In their study they found that shrubs contributed 65% while trees contributed 35% of the total composition. They also reported that some human activities like cattle overgrazing, cutting down of trees for firewood, house construction and charcoal burning were some of the major threats to the forest. Alelign et al. (2007) reported that tree logging was a common activity and the only source of income was selling of fuel wood and this kind of activity is unsustainable since it leads to loss of woody plants especially the shade trees in the long run. He worked on the rejuvenation condition and the diversity of woody plants species in Ethiopia. In Mexico Almazán-Núñez et al. (2016)

conducted a study to analyse the changes in woody plant species of pine-oak forest at three stages: early, intermediate, and mature stages and they recorded 892 woody plants species in the three successional stages belonging to 20 families. In Bangladesh, Feroz et al. (2016) recorded 40 plant species from 25 plant families and 37 genera. Euphorbiaceae and Moraceae were the most species-rich families with four species each. In India, Singh et al. (2016) reported 18 tree plant species in total belonging to 12 families and 16 genera. Neelamegam et al. (2016) reported 50 woody plants in total from 29 plant families and 50 genera with 872 individuals.

Masresha et al. (2015) in Ethiopia recorded 124 plant species, from 112 genera and 65 plant families. In their study trees, shrubs and herbs contributed 42%, 29% and 29% respectively of the total vegetation composition. Savadogo et al. (2007) in Tiogo forest in Burkina Faso recorded 89 species in total belonging to 29 families and 66 genera, of which 67, 60, 35 and 23 species were encountered in dense woodland, open woodland, fallow and gallery forest respectively with Combretaceae and Fabaceae as the most abundant families. Froumsia et al. (2012) in Cameroon recorded 86 plant species in total from 58 genera and 28 families. The most species-rich families were Fabaceae- caesalpinioideae, Fabaceae-mimosoideae and Combretaceae.

2.3 Trends in vegetation cover and impacts of land use on vegetation cover and density

Vegetation is considered as an important intermediate link in the earth's atmosphere and hydrosphere, and its dynamics plays a crucial role in maintaining the functioning of the earth's diverse ecosystems and their services provision (Wang et al., 2011). Vegetation also exerts significant influence on water balance and on the regulation of carbon cycle (Tucker et al., 2001). However, a growing number of studies have shown that vegetation growth has been strongly influenced by global change in recent decades (Tucker et al., 2001). Climate variability and land use change have been recognized as two important factors influencing vegetation dynamics under global change (Adepoju et al., 2019). While land use changes are linked to changes in the hydrological processes and biodiversity loss, climate variability, especially precipitation and temperature, is more closely associated with changes in phenology, respiration, and ecological balance. Reduction in the cover of woody vegetation leads to reduced capacity and loss of biodiversity, reduced watershed protection, increased soil erosion and the consequential impacts being decrease in the availability of many products and services and ecosystem instability (Gojamme and Tanto, 2016).

Vegetation cover data have been collected primarily for use in plant ecological descriptions or range condition assessments. In studies to describe plant ecological features cover data is used to document the relative abundance of the various plants comprising a plant community. There is, on the other hand, typically relatively little importance in knowing the accurate absolute percentage cover. In fact, cover data for plants from different strata are included in the same table causing total cover reported to exceed 100 percent, which is of no concern. In rangeland condition determinations, it is the relative proportion of species that is of interest, not the absolute cover value (Buckner, 1985).

Gojamme and Tanto (2016) in a study to determine the composition and diversity of woody plant in Ethiopia recorded a density of 210.792/ha for the 26 to 50 cm DBH class and a density of 76.208/ha for the 51 to 60cm DBH class representing shrubs or trees. The density was increasing with increase in number of species thus forming an inverted J-shaped for the most selected dominant trees species. The major human activities that contributed to the decrease in woody plant species in the area included; charcoal production, overgrazing, cutting trees for the construction of houses and for firewood. Alelign et al. (2007) reported a density of 3318 of woody plant species in Ethiopia. Naidu and Kumar (2016) carried a study in India to determine the diversity of trees, the structure of the stand and the composition of the community of tropical forest and they reported that the density of the trees was ranging from 435 ha^{-1} to 767 ha^{-1}. Abunie (2016) in Ethiopia, sought to determine the regeneration status and diversity of woody plant species of Yemrehane Kirstos Church Forest in Ethiopia and reported densities of 514.7, 415.4 and 506.6 individuals ha^{-1} for saplings, seedlings and mature woody species respectively. Over 65% of the total density was constrained in the middle and higher diameter class (5-32cm), whereas, the rest of density were confined to the lower diameter classes (1-5 cm). This indicated that there was increased cutting down of trees in the lower classes by the local dwellers for various purposes like for fuel wood and fencing and for agricultural expansion in addition to livestock trampling or browsing. Bekele (1993), found a density of 544 individuals/ha and this was mainly comprised of shrubs and small sized trees. Similarly, Fisaha et al. (2013) in Wof Washa Natural forest in Ethiopia recorded 699 individuals/ha of woody plants which comprised of more small sized trees and shrubs since the density of large sized trees was highly decreased and shrubs and small sized trees had become more dominant. Other studies and their results are; 1293 individuals/ha in Dodola forest (Hundera et al., 2007) and in Bale Mountains national park Yineger et al. (2008) recorded a total of 898 individuals/ha.

CHAPTER THREE

3.0 GENERAL MATERIALS AND METHODS

3.1 Description of the study area

This study was carried out in Rusinga Island situated in Homa Bay County, within Lake Victoria region. The Island lies between latitudes 0°35' and 0°44' South and longitudes 34°11' and 34°22' East. The altitude of the area varies between 1100 and 1300 m above sea level and covers an area of 44 km^2 (Homan et al., 2015). The Island is divided into two locations namely Rusinga East and Rusinga West and there are six Sub-locations, which include Kaswanga, Wanyama, Kamasengre East, Kamasengre West, Wawere South and Wawere North. In Rusinga Island there are about 10 beach communities and a total of 36 villages (Olanga et al., 2015). Due to the closeness of the island to the mainland, in the year 1983, a 200m long causeway was constructed to link the Island with Mbita town, which is the main administrative and trading centre (Osoro et al., 2016; Ketelaars, 2015).

Rusinga Island's terrain is hilly and rocky with Ligongo hill being the main hill at the centre of the Island (Olanga et al., 2015). The temperatures range from 16 and 34°C daily and tend to be higher in June and October (Homan et al., 2015). Rusinga Island's annual rainfall varies from 800 to 1000 mm with an unequal distribution over the year greatly influenced by relief and altitude. The Island has two seasons of rain, the short rainy season, which occurs from October to December, and the long rain season, which is the most important occurring in March, and ending in June. However, the seasons are becoming less predictable with the amount of rainfall received being highly variable in both space and time (Opiyo et al., 2007; Ketelaars, 2015). In most of the years, the amount of rainfall received in the area is too low for growing crops and the evaporation rate is very high (Weckenbrock and Oldesloe, 2004).

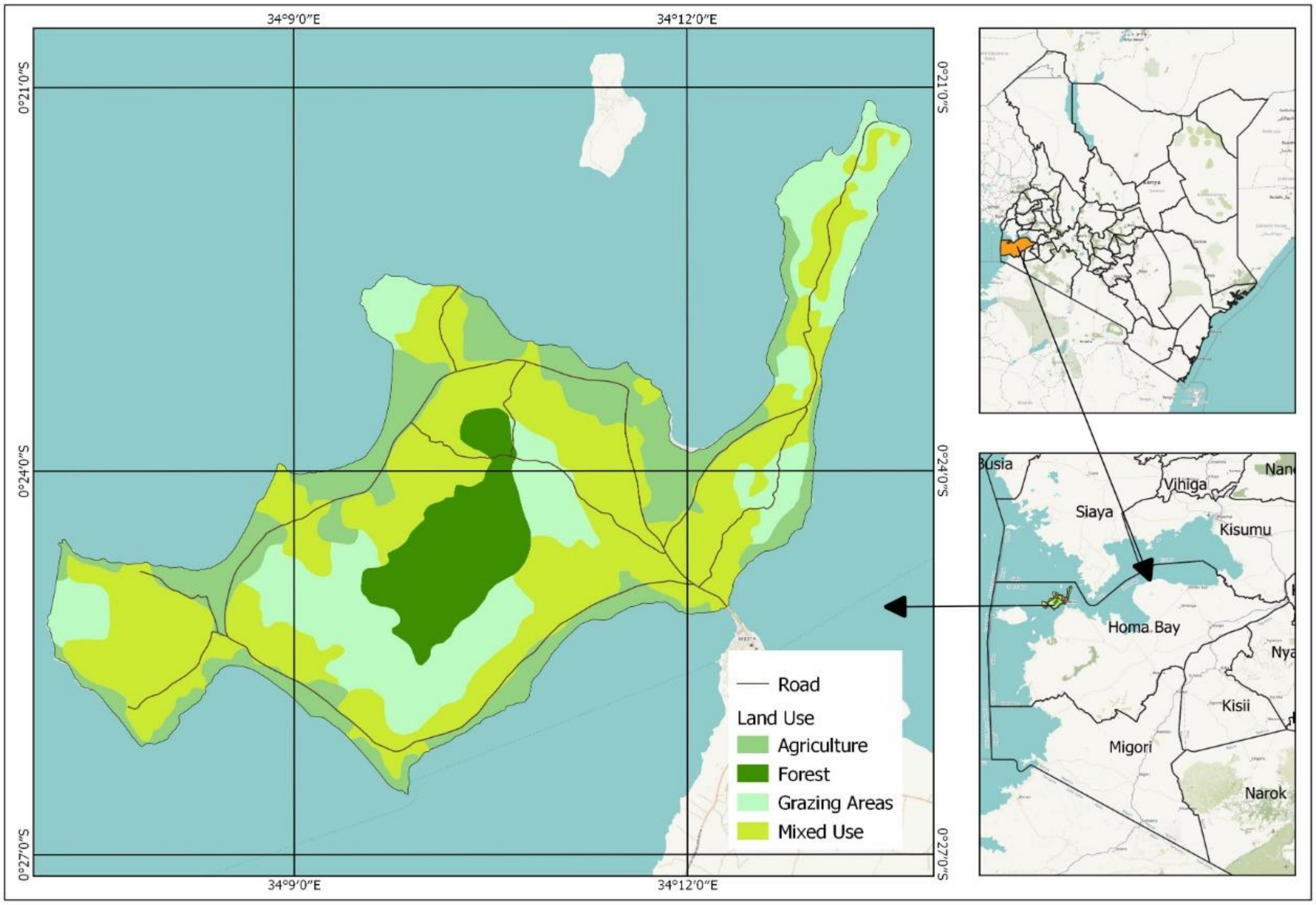

Figure 3. 1: Map of the study area

3.1.1 Vegetation and Soil types

The major flora cover in Rusinga Island is made up of shrubs but there is very high deforestation on the Island (Olanga et al., 2015). The soils of Rusinga Island originated from volcanic rocks and are of low to very low fertility due to the colluvium within the volcanic rocks, thus limiting the agricultural potential of the Island (Conelly, 1994).

3.1.2 Water resources

There are several seasonal rivers, which contain water only during the rainy season, and the lake provides the main water source for the population (Opiyo et al., 2007). Two rainy seasons are typical for the area, the 'long rains' between March and June and the 'short rains' between

October and November, but these seasons are unreliable with some years characterised by prolonged dry periods.

3.1.3 The people and Economic activities

Most the inhabitants in Rusinga Island identify themselves as Luo or Luo-Abasuba. The Abasuba were the early Bantu-speaking inhabitants of the area, originally from Uganda, who have been largely assimilated by the Nilotic Luo (Conelly, 1994). The Luo are believed to have begun their migration into Siaya and South Nyanza in Kenya from north during the eighteenth century and they are the dominant ethnic group in the lakeshore region (Conelly, 1994). Rusinga Island has around 25,000 inhabitants who generally speak the DhoLuo language together with Swahili, which is a national language (Homan et al., 2015). The main occupational activities in Rusinga Island are subsistence farming of crops like Sorghum, maize, millet and adult males normally carry out fishing that with females involved in fish processing and trading (Weckenbrock and Oldesloe, 2004). Moreover, less than half of the total area can be used for agriculture because some parts of the island are very steep and unsuitable for cultivation while others are used for roads and homesteads. Fish net repair and boat making are other activities that are carried out in Rusinga Island (Weckenbrock and Oldesloe, 2004).

3.2 Research design

3.2.1 Socioeconomic sampling

A total sample size of 150 households from the six sub-locations in Rusinga Island was selected for household interviews. The number of households selected for sampling was determined proportionately according to the total number of households in each sub-location. Semi-structured questionnaires were administered to the 150 randomly selected households from the six sub locations (Table 3.1). The questionnaires comprised of both the open and close-ended questions (Appendix 1). Some of the information gathered was the perceptions on the changes in vegetation composition and abundance, factors influencing the vegetation status and dynamics and the suggested management strategies for the environment.

Table 3. 1: Number of households selected for interviews in Rusinga Island

Location	Sub-locations	Total number of households	Selected Number of households
	Kamasengre East	791	17
Rusinga West	Kamasengre West	1278	27
	Wanyama	917	19
	Kaswanga	562	12
	Waware South	1410	30
Rusinga East	Waware North	2117	45
	Total	**7045**	**150**

Purposive and snowballing sampling techniques (Tongco, 2007; Shafie, 2010) were used to select respondents for Focus Group Discussions (FGDS) and Key Informant Interviews (KIIS) (Appendix 2 and 3). Purposive sampling method involved selection of individuals in Rusinga Island with an enormous understanding of woody plants that existed before and what changes had occurred. Snowballing method involved a referral technique where interviewed people especially the herbalists in the area were requested to identify and direct the interviewer to other herbalists who are well-informed about the subject of discussion. This was important to collect information on plants species used for medicine. In total, 4 focus group discussions were conducted, comprising of 8-12 men and women participants. Thirty (30) KIIs were conducted and the participants were chosen based on their roles in the community, age group and gender. They included clan elders or village elders, the local administration and former area leaders, herbalists, Environmental conservation officers in charge of Rusinga Island, Kenya Forest Service (KFS) officers, Women and youth group leaders involved in environmental conservation activities and the community forest guards mandated to watch over any illegal activities carried out in the area.

3.2.2 Ecological sampling

Purposive sampling technique was used where three main hills: Ligongo, Kabade and Wanyama were selected as reference points to capture the variations in land use gradient from the lowlands through to the hilltops. The slopes of the hills were demarcated into three study zones: lower, middle and upper zone (Figure 3.2) differentiated by the land use and dominant vegetation types. The three zones were:

i) Lower zone: Dominated by crop farmlands and exotic tree species

ii) Middle zone: Characterized by more settlements and dominated by both indigenous and exotic plant species.

iii) Upper zone: This is mainly the grazing lands dominated by indigenous plant species.

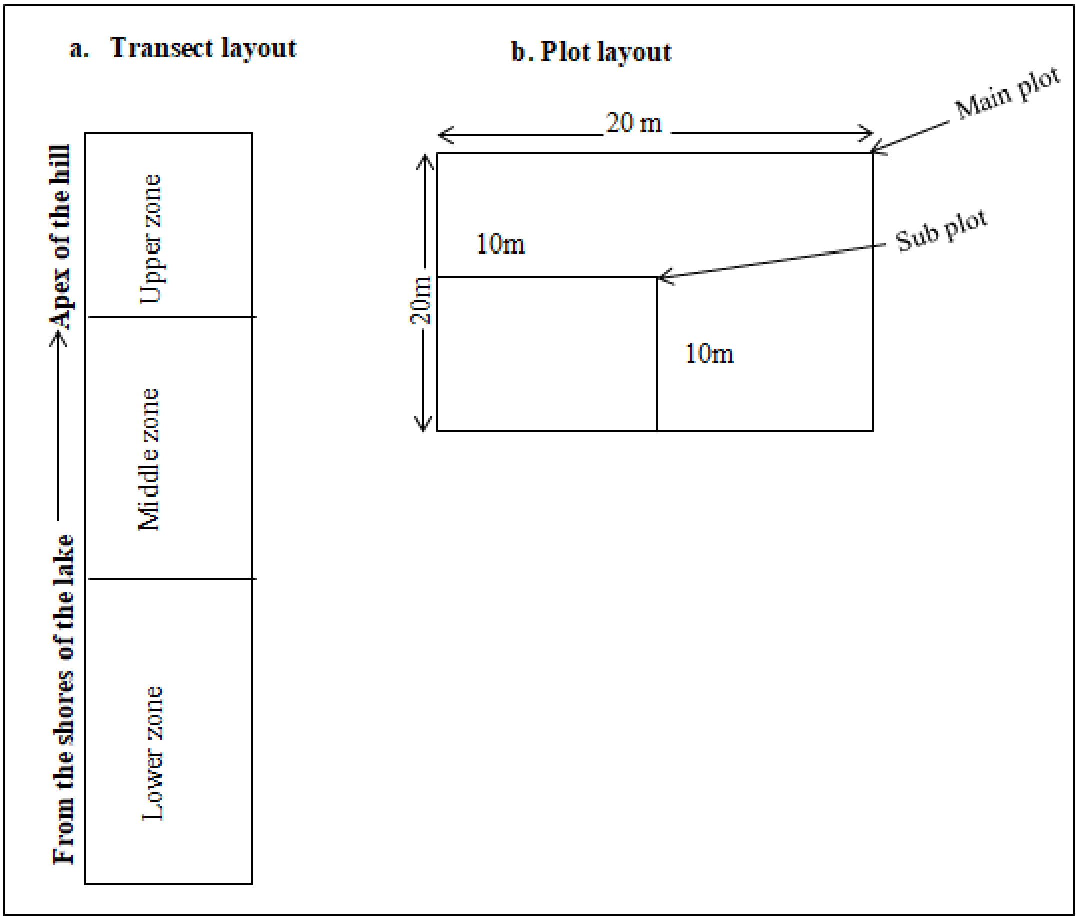

Figure 3. 2: An illustration of a transect and plot layout

On each hill, four transect lines cutting across the three study zones were demarcated starting from a common point at the apex of the hill and radiating to the four sides of the hill to the shores of the lake following the four directions of a compass (East, West, North and South). In all the study zones and hills, 98 sampling plots in total measuring 20 m x20 m (400m^2) for recording tree species and one subplot of 10 m by 10 m within the main plot for recording shrubs and lianas (Figure 3.3) were systematically demarcated at an interval of 200 m. The sampling plots were allocated according to the relative sizes of the study zones. Any woody plant species observed in each plot was classified according to their plant form i.e. tree, shrub or liana, recorded and counted at the individual level (Buckland et al., 2007). The data was used to compute the woody species diversity, composition and density.

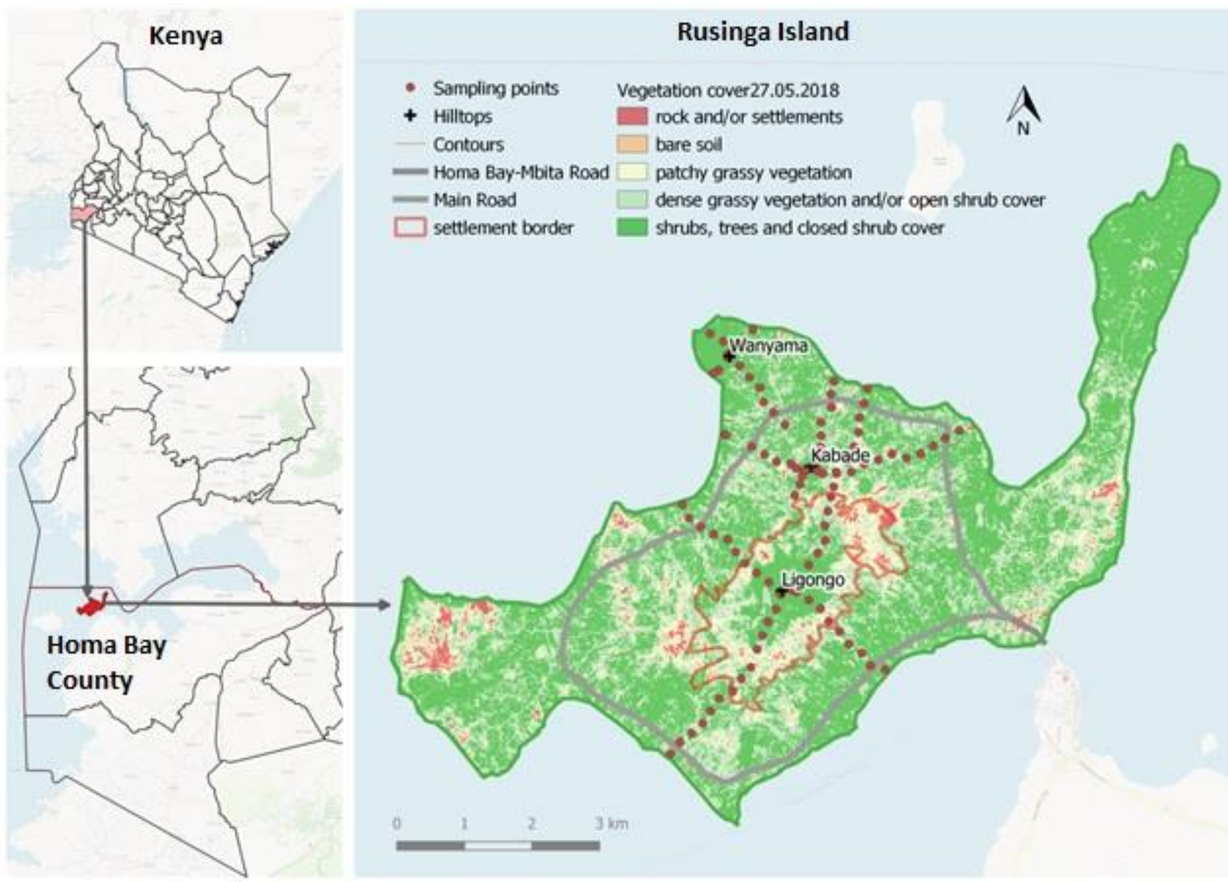

Figure 3.3: Map of the study area showing the sampling points

A line intercept method was used to determine the cover of woody plants on the three hills and at the three different study zones (Figure 3.4). The method is accomplished by stretching a tape across the vegetation and measuring the length along the tape occupied by the foliage of the plants in vertical projection (Canfield, 1941). The observer moves along the transect line classifies the plants intercepted by the tape and records the intercept distance. In this study, a 20m measuring tape was systematically placed along the predetermined transect lines at an interval of 200m, and any woody plants intercepted by the tape were identified and intercept distance recorded for determination of basal cover. The distance of the tape intercepted by a species was divided by the total length of the tape and this estimated the percentage of the area covered by that species.

Other data collected within each plot were the geographical location (UTM coordinates) and elevation (m) using a GPS to come up with study area maps and to map out the exact locations where vegetation sampling was carried.

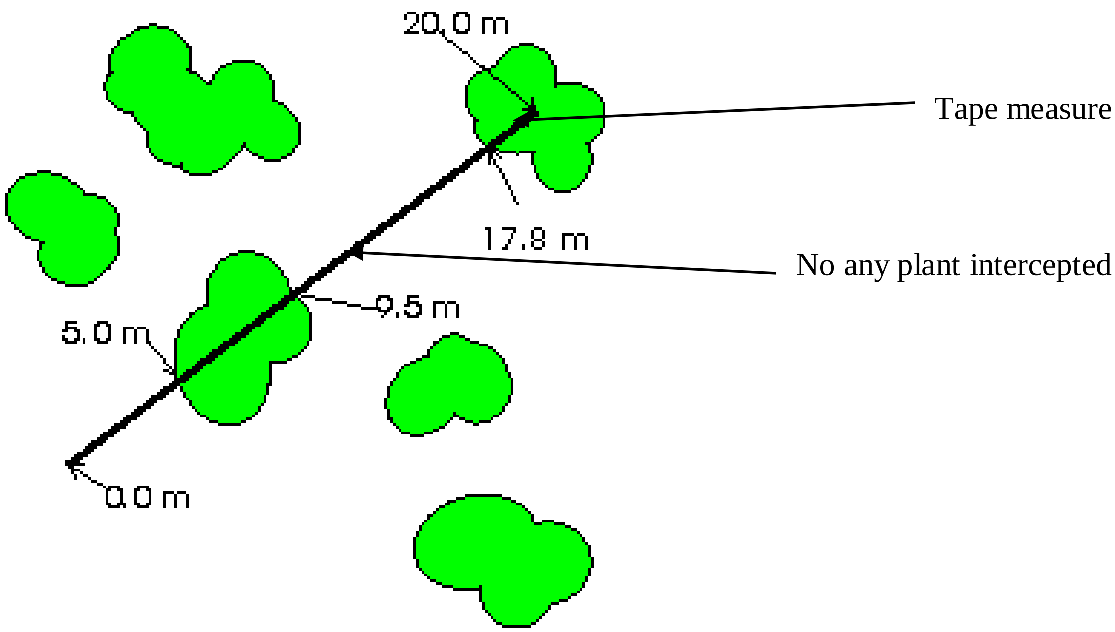

Figure 3. 4: Illustrations of a line intercept method

Source: http://oregonstate.edu/instruct/bot440/wilsomar/Content/HTM-perarea.htm. Accessed on 27/01/2020

The inventory was conducted during the rainy season from May to July 2018 for ease of species identification and sample collection. All the trees, shrubs and lianas encountered were identified in the field with the aid of a botanist and grouped according to species type. Those plant species which were not well-known were recorded with their local names and a quick herbarium collected and prepared using a plant press and taken to the University of Nairobi taxonomy laboratory for identification as explained by Tabuti (2007).

CHAPTER FOUR

COMMUNITY PERCEPTIONS ON THE USES AND CHANGES IN WOODY PLANTS COMPOSITION AND ABUNDANCE IN RUSINGA ISLAND, HOMA BAY COUNTY, KENYA

ABSTRACT

Local communities have been coping with environmental dynamics since time immemorial, and they often possess considerable knowledge on the changes in environment and the mechanisms of coping with the consequences of such changes. Local people's knowledge on the changes in vegetation composition and abundance is thus imperative in informing on effective and appropriate management and conservation strategies to ensure sustainability in the utilization of natural vegetation resources. A random sampling design was employed to select 150 households for interviews in addition to key informant interviews (*n*=30) and focus group discussions (*n*=4) to acquire information on the communities' perceptions on the status of vegetation in Rusinga Island and the suggested management strategies for the environment, particularly the woody vegetation resources. Majority (86%) of the respondents reported having observed changes in vegetation composition and abundance in the study area. The changes were attributed to deforestation, high human population, overgrazing, inadequate rainfall, and soil erosion. Most (68%) of the respondents perceived the changes had occurred mainly in the forests/hills, in the entire Island (15.3%) and in the homesteads (2.7 %). To reverse the changes, the local community proposed tree planting, protection of existing trees, use of alternative sources of fuel, increased awareness creation on environmental conservation and controlled livestock grazing as the best strategies to reduce vegetation degradation. Besides sensitization and building capacity of the communities to engage in sustainable management of vegetation resources, land rehabilitation interventions should target the plant species at risk through re-introduction and re-afforestation practices.

Keywords: Local knowledge; vegetation changes; woody plant species; household interviews; Rusinga Island

4.1 INTRODUCTION

Globally many plant species are decreasing at alarming rates driven majorly by the expansion of agricultural fields and ever-increasing demand for plant resources by the local people who depend on the natural resources as a source of livelihood. These trends are believed to be the cause of extensive losses in biodiversity and ecosystem goods and services (Strauch et al., 2016). The decline of some plant species decreases the cover of vegetation thus exposing the soil surface to water and wind erosion resulting into increased land degradation (Wezel and Haigis, 2000). Deterioration in the status of natural vegetation results into a clear decline in most of the highly valuable benefits derived from those resources with an apparent effect on local people's daily lives (Lykke, 2000).

As elsewhere, the biodiversity of Africa is not only seriously threatened on its mainland but also on the islands (IUCN, 1990). This is largely attributed to the rapid growth in human population thus exerting more pressure on the plant resources. The condition is more serious on the islands, because of anthropogenic influences in addition to their own natural limits thus demanding special attention since they are fragile ecosystems (Zegeye et al., 2006). In particular, the local people residing in Rusinga Island encounter several problems like extensive deforestation (Ketelaars, 2015), and prolonged periods of droughts which substantially impact the local ecosystems, agriculture, biodiversity and human well-being (Opiyo et al., 2007). Although clearance of land for cultivation and firewood explain the current high rates of changes in vegetation cover, the changes in vegetation diversity are mostly caused by deforestation (Mlotha, 2001). As observed in previous studies (Celentano et al., 2014; Dickinson et al., 2017; Ouko et al., 2018; Sop and Oldeland, 2011; Ibrahim, 2017; Joshi et al., 2009; Kangalawe, 2012) deforestation and woody plants' degradation through fuel wood collection and overgrazing are among the main causes of changes in vegetation. In addition, land-use change, loss of soil fertility and heavy grazing induces variations in the structure and composition of vegetation with a robust decrease in the diversity of species (Hiernaux et al., 2009).

Even though various species of plants are subjected to unsustainable harvesting and overexploitation, woody plant species are more vulnerable due to their longevity, large size, low reproductive rates and poor dispersal capacities rendering them more prone to local extinction (Tabuti et al., 2009). Woody plants offer suitable conditions for the growth of herbaceous plant species by increasing the soil fertility and improving the microclimatic conditions. Additionally, they are a source of fodder in the dry season for both the wildlife and livestock especially the browsers (Lykke et al., 2004). Overexploitation of most of woody plant species is typically influenced by the patterns of use of plant resources, which are generally affected by cultural, political and economic factors (Ticktin, 2004). The loss of indigenous woody plant species may jeopardize the livelihoods of the local communities who normally rely on them thus increasing their poverty levels. Thus, there is a need for such resources to be managed sustainably and this requires the availability of information on the locally valued and preferred species, their status, any positive or negative changes that may have occurred and the proposed management strategies by the local communities (Lykke, 1998). Since time immemorial the local communities have been coping with the changes in their environments thus, they often have an extensive knowledge about environmental changes and means to cope with their consequences (Bowman, 2002). Such knowledge not only compels for a scientific investigation on the causes of the changes but also helps in the design of adaptation and mitigation measures to deal with changes in vegetation since the local people express their interests and desire for an improved management strategy (Ouédraogo et al., 2014).

Community-based studies provides valuable information that helps in the recognition of the hindrances for their involvements in community development activities and the reasons as to why they continue using the same land degradation causing practices (Davies et al., 2010). The local people hold detailed and reliable information about changes in vegetation, thus their knowledge is key in the awareness of the long-term changes in vegetation composition and abundance (Kinlund, 1996). Moreover, the elderly people can give reliable information on the changes that have occurred in vegetation over a certain period (Lykke, 2000). However, there is no available data on vegetation resources found in Rusinga Island, their historical changes and status. According to Zegeye et al. (2006) most of the Islands are insufficiently studied due to lack of recognition and most of them are not easily accessible by researchers leading to limited information on the island's biota. The objective of the current study was therefore to assess the different uses of woody plant species, the perceptions of the local people on the changes in vegetation, the causes of the changes and their proposed management approaches to make sure that the woody plant resources will be available in future.

4.2. DATA COLLECTION AND ANALYSIS

Data collection was done through household interviews using semi-structured questionnaires complemented by Key informant interviews (KIIs) and Focus group discussions (FGDs) described in Chapter 3. The acquired data from household interviews were analysed using Statistical Package for the Social Sciences (SPSS) Version 25 to generate descriptive statistics on the socio-demographic characteristics of the respondents and their perceptions on the changes in vegetation composition and abundance. Data on this was presented in tables to show the number of respondents and their perception of the drivers of changes. A nonparametric Chi-square test was used to determine if there were statistically significant differences in household characteristics among the respondents and their perceptions on the changes in vegetation composition and abundance. Participants' responses and discussions from the KIIs and FGDs were combined and summarized into different topics to complement and substantiate the responses from the individual household interviews.

4.3 RESULTS AND DISCUSSIONS

4.3.1 Socio-demographic characteristics of households in Rusinga Island

Majority (64%) of the households are headed by males compared to only 36% headed by females. The large number of households headed by males is ascribed to the strong culture and tradition of the community which states that a man is the head of the family and the woman can only take up the role after the death of the husband (Rotich, 2016).

Majority of the household heads were between 31-60 years (59.3 %) followed by those over 60 years (34.7%) and below 30 years of age being represented by 6% (Table 4.1). Therefore, most of them were more familiar with the area, the resources that are derived from the woody plants and the changes that may have taken place in vegetation and their respective causes. Aged people have a broader knowledge and can understand the socioeconomic and ecological dynamics-taking place in an area (Kaganga and Ndumbaro, 2017). The results also indicated that household size ranged from one person to 14 people, with an average of 5 persons. The household farm size varied from 0.25 to 10 acres, with an average of 1.4 acres and majority (87.3%) owned less than 5 acres of land. With respect to their level of education, majority (60%) of the respondents had attained primary education, secondary education (27.3%), tertiary education (2.7%) and 10% had never attended school (Table 4.1).

The main source of livelihood as reported by the respondents was small scale farming (34%), followed by business (32%), fishing (18%) and formal employment (3.3%). This is attributable to the declining levels of fish in Lake Victoria thus the residents are opting to practice small-scale farming and business as a source of income. Similarly, Ketelaars (2015) and Balirwa et al. (2003) found that many families in Rusinga Island were attempting to practice other forms of generating income. Examples include agriculture both for commercial and subsistence purposes and this was attributable to "lack of fish" in the lake, making the fishing activity less viable and unreliable as a source of income and a way of sustaining a family.

Table 4. 1: Demographic and social characteristics of respondents

Household characteristics	**Number of respondents (N=150)**	**Chi-square (χ2) value**	**P-value**
Gender of the household head		11.76	0.001
Male	96(64)		
Female	54(36)		
Age of household head		64.12	0.000
Under 30 years	9(6)		
Between 31-60 years	89(59.3)		
Over 60 years	52(34.7)		
The education level of the household head		117.25	0.000
None	15(10)		
Primary school	90(60)		
Secondary school	41(27.3)		
Post-secondary level	4(2.7)		
Source of livelihood		50.67	0.000
Small scale farming	51(34)		
Fishing	27(18)		
Business	48(32)		
Formal employment	5(3.3)		
None	19(12.7)		
Land size owned (acres)		198.52	0.000
None	16(10.7)		
Below 5 acres	131(87.3)		
6-10 acres	3(2.0)		
Average land size owned (acres)	1.4 ± 1.54		
Average household size	5 ±3		

Source: Household interviews (N=150); percentages are given in parentheses

4.3.2 Utilization of woody plant species by the local people of Rusinga Island

The respondents reported various uses of woody species, among them, fencing, construction, firewood, medicine and forage and fodder (Table 4.2). The local people seemed to prefer species such as *Acacia seyal, Senna siamea, Balanites aegyptiaca, Euclea divinorum, Leucaena leucocephala* and *Markhamia lutea* for firewood. The community revealed that these species are mostly used because they burn with minimal smoke and last longer while cooking. Similar results by Ouédraogo et al. (2014) in a study conducted in Pama area of southeastern Burkina Faso found that some specific trees were preferred for firewood because they burn without much smoke. *Senna siamea, Markhamia lutea, Olea africana, Leucaena leucocephala* and *Euclea divinorum* were preferred for construction purposes. There was an overlap of species that were used for firewood and those preferred for construction. For instance, *Senna siamea* is a valuable firewood species and at the same time, it is used for construction since it is resistant to termite attacks. Kristensen observed similar results of an overlap between species uses for firewood and construction and Balslev (2003), who reported an overlap of five most preferred species for construction and the five most favoured species for firewood in the Gourounsi ethnic group in Burkina Faso. This observation is also supported by Lykke et al. (2004), who noticed a substantial association between construction and firewood species for the Fulani ethnic group in the Sahel of Burkina Faso. The local people preferred trees, which are hardwood since they are not easily destroyed by termites and with straight trunks for the construction. Lykke (2000) observed that local people choose trees with consistent wood and straight trunks, such as *Markhamia lutea*, for construction purposes. In a study done by Gonçalves et al. (2018) in Sucruiu community, of Northeastern Brazil, the local communities reported a decrease in the accessibility of plants used for fuel wood and an increase in the accessibility of plants used as medicinal plants. The respondents pointed out that all the plant species were generally decreasing but the most affected species were those used for firewood and charcoal, thus they considered firewood scarcity as a very big problem in the area compared to the past. Contrary to Gonçalves's observations, Lykke (2000) in Fathala Forest, West coast of Senegal observed that the tree species that were used for firewood were increasing and firewood was not considered as a scarce resource while those used for the construction purposes were decreasing.

Table 4. 2: Uses of different woody plant species reported by communities in Rusinga Island

Species	***Uses***					**Total number of uses**
	Construction	***Fuel (firewood& charcoal)***	***Medicine***	***Fencing***	***Forage/Fodder***	
Acacia brevispica		*x*				*1*
Acacia seyal	*x*	*x*			*x*	*3*
Albizia coriaria	*x*	*x*	*x*			*3*
Azadirachta indica			*x*		*x*	*2*
Balanites aegyptiaca		*x*			*x*	*2*
Caesalpinia decapetala				*x*		*1*
Carrisa spinarum L			*x*	*x*	*x*	*3*
Commiphora africana			*x*			*1*
Cordia ovalis		*x*				*1*
Dovyalis caffra				*x*		*1*
Eucalyptus species	*x*					*1*
Euclea divinorum	*x*	*x*	*x*		*x*	*4*
Euphorbia tirucalii		*x*		*x*		*2*
Ficus species					*x*	*1*
Grevillea robusta	*x*					*1*
Grewia bicolor	*x*	*x*	*x*		*x*	*4*
Harrisonia abyssinica			*x*	*x*	*x*	*3*
Lanea schimperi			*x*			*1*
Lantana camara		*x*		*x*	*x*	*3*
Leucaena leucocephala	*x*	*x*			*x*	*3*
Markhamia lutea	*x*	*x*				*2*
Melia azadirach			*x*		*x*	*2*
Moringa oleifera			*x*		*x*	*2*
Olea africana	*x*	*x*				*2*
Searsia natalensis	*x*	*x*	*x*		*x*	*4*
Senna didymobotrya			*x*			*1*
Senna siamea	*x*	*x*			*x*	*3*
Sesbania sesban					*x*	*1*
Terminalia brownii	*x*		*x*			*2*
Thevetia peruviana		*x*	*x*	*x*	*x*	*4*
Ximenia caffra			*x*			*1*

Source: Household interviews (N=150)

4.3.3 Local perceptions on the changes in vegetation composition and abundance

According to this study, most (86%) of the respondents had observed changes in vegetation composition and abundance in the study area during the last 30 years. Deforestation (43.3%), high human population (15.3%), overgrazing (10.7%), inadequate rainfall (10%) and soil erosion (6.7%), were mentioned by the respondents as the major causes of the changes in vegetation in the study area (Table 4.3). This concurs with the results of Sambou et al. (2016) and Wasonga et al. (2011) in Senegal and Kenya, respectively who reported similar causes of vegetation changes in their study areas. Similarly, Zegeye et al. (2006), in Ethiopia found that cutting down of trees for various purposes was the main threat to the vegetation resources in their study area. In contrast, Lykke (2000) in Senegal reported that only a few respondents considered logging as a cause and instead perceived frequent and intense fire and inadequate rainfall as the major causes of vegetation changes. Majority of the respondents who perceived there were changes in vegetation composition and abundance reported the changes had mainly occurred in the forest/hills (68%), in the entire Island (15.3%) and in the homesteads (2.7%) (Table 4.3). The respondents also reported increased soil erosion (24%), lack of firewood (11.3%), lack of building materials (6%) and the presence of few and small-sized trees (44.7%) as the indicators and impacts of the changes. Perception is a personal view, whereby different people may perceive the same phenomenon in a different way depending on the features of the situation they choose to selectively absorb, how they organize this information and the way they interpret it to obtain a grasp of the situation (Ingold, 2000).

Table 4. 3: Community perceptions on the changes in vegetation composition and abundance

Variables	Number of respondents (N=150)	Chi-square ($\chi 2$) value	P-value
Are there changes in vegetation		77.76	0.000
Yes	129(86)		
No	21(14)		
Where the changes have occurred		153.73	0.000
Entire island	23(15.3)		
Forests/hills	102(68)		
Homesteads	4(2.7)		
Not applicable/No changes	21(14)		
Causes of the changes		81.040	0.000
Deforestation	65(43.3)		
High population growth	23(15.3)		
Overgrazing	16(10.7)		
Inadequate rainfall	15(10)		
Soil erosion	10(6.7)		
No changes/causes	21(14)		
Signs of the changes		69.87	0.000
Few and small-sized trees	67(44.7)		
Increased soil erosion	36(24)		
Inadequate supply of firewood	17(11.3)		
Insufficient supply of building materials	9(6)		
No changes	21(14)		
Proposed restoration strategies		134.77	0.000
Planting trees	76(50.7)		
Protection of existing trees	24(16)		
Use of alternative sources of fuel	13(8.7)		
Increased awareness creation on environmental conservation	10(6.7)		
Controlled livestock grazing	6(4.0)		
No changes	21(14)		

Source: Household interviews (N=150); percentages are in parentheses

4.3.4 Community's suggestions on restoration of vegetation cover in Rusinga Island

The local people proposed several adaptation measures as a result of the decreasing availability of trees which are of high socio-economic importance as has been reported in some studies (Sambou et al., 2016; Wezel et al., 2000). Interestingly, half of the respondents (50.7%) from the household interviews recommended planting more trees as a way of reducing vegetation degradation (Table 4.3). Other proposed restoration strategies were; protection of existing trees (16%), use of alternative sources of fuel (8.7%), increased awareness creation on environmental conservation (6.7%) and controlled livestock grazing (4 %). Similarly, Celentano et al. (2014) reported that more than half (56%) of interviewees in their study proposed planting trees as the best strategy to reverse the observed changes in Pepital River watershed in Brazil. Celentano et al. (2014), reports that in order to overcome the continuing degradation of tropical forests planting trees ought to be considered as the best strategy. Discovering ways to restore tree diversity in the natural ecosystems helps in meeting the numerous needs of rural people and should be given appropriate precedence while developing policies. Additionally, Nsiah-Gyabaah (1994) states that when local people notice any deterioration in their environment, they become more concerned about environmental changes and they will try to limit some of their activities and practices that lead to land degradation. Involvement of the local people in devising and execution of restoration programs is crucial (Ramakrishnan, 2007).

A total of 42 woody plant species both exotic and indigenous were mentioned by the informants to be found in Rusinga Island at present and about 30 years ago. Out of these, 9 woody plants corresponding to 21% of all the identified woody plant species found in Rusinga Island were proposed for a reforestation programme. Some of the most preferred species for rehabilitation were: *Markhamia lutea, Senna siamea, Leucaena leucocephala, Olea africana* and *Euclea divinorum* (Table 4.4) and most of the respondents cited resistance to drought and their uses like construction materials, source of firewood and livestock fodder as the main reasons for their preferences. The motivation of people and their commitments to restoration programs are commonly related to the usefulness of species of plants and the desired environmental goods and services (Dalle and Potvin, 2004). A total of 7 species were identified as the least preferred species for reforestation (Table 4.4). Some of the least preferred species were *Thevetia peruviana, Eucalyptus species, Terminalia mantaly, Acacia seyal* and *Euphorbia candelabrum.* The respondents cited harbouring of snakes by some species like *Thevetia peruviana,* the requirement of a lot of water for some species to grow, myths of some species causing deaths in the family and some taking very long time to grow.

Table 4. 4: Woody plant species mentioned in order of preference for land rehabilitation in Rusinga Island

Most preferred species	Reason for preference	Least preferred species	Reason for non-preference
Markhamia lutea (21)	Compatible with agricultural crops, fast growing and coppicing properties	*Terminalia mantaly (10)*	Associated with death of family members because of the arrangement of its canopy.
Senna siamea (15)	Adaptable to the local climatic conditions	*Eucalyptus species (8)*	Requires a lot of water to grow and causes the drying out of an area.
Leucaena leucocephala (14)	Fodder for livestock and improves soil fertility	*Thevetia peruviana (7)*	Provides hiding places for the green snakes which are poisonous to children, spreads out very fast and reduces the fertility of the soil.
Olea africana (6)	Good for building houses, firewood and resistant to drought	*Acacia seyal (3)*	Takes a very long time to grow
Euclea divinorum (5)	Good for building, firewood, medicinal and adaptable to the local climatic conditions	*Euphorbia candelabrum (3)*	Believed to be a bad omen as it causes death in a family and it is not mostly found in homesteads
Azadirachta indica (5)	It is a medicinal plant species	*Balanites aegyptiaca (2)*	Takes a very long time to grow
Grevillea robusta (4)	Compatible with agricultural crops, source of firewood and timber for construction	*Ficus species (2)*	Takes a very long time to grow
Rhus natalensis (4)	Adaptable to the local climatic conditions		
Terminalia brownii (2)	Drought resistant and good for building houses		

Source: KIIs (N=30) Number of informants who mentioned each species is given in parentheses

4.4 CONCLUSIONS AND RECOMMENDATIONS

This study showed that majority of the people in Rusinga Island are cognizant of the decline in woody vegetation in their area and the possible driving factors affecting the vegetation dynamics. Most of the local people perceived the leading causes of the changes being deforestation, high human population, overgrazing, inadequate rainfall, and soil erosion. This study has documented that the woody vegetation of Rusinga Island is highly dispersed and that all the forest trees are declining in abundance. For woody plant species to be effectively conserved and managed, the local people must be actively involved in the management and rehabilitation efforts. In addition, local ecological knowledge should be incorporated in ecological resource management, particularly at the local level. Some of the most preferred plant species for reforestation like *Markhamia lutea, Senna siamea, Leucaena leucocephala, Olea africana* and *Euclea divinorum* identified by the local people should be encouraged and promoted.

CHAPTER FIVE

WOODY PLANT SPECIES DIVERSITY, DENSITY AND COVER IN RUSINGA ISLAND, HOMA BAY COUNTY, KENYA

ABSTRACT

Woody plant resources play a vital role in the provision of goods and ecosystem services that contribute to households' livelihoods. However, the ever-increasing population pressure and its associated effects threaten these resources. The diversity, density and cover of woody plant species in Rusinga Island were studied to understand the status with a goal to inform effective management and conservation measures. A purposive sampling approach was adopted to select three hills (Ligongo, Kabade and Wanyama) as reference points to capture the variations in land use gradient from the lowlands through to the hilltops. The slopes of the hills were demarcated into three study zones: lower, middle and upper zone differentiated by the dominant vegetation types and land use. Line transect in combination with sampling plot methods were used during data collection. Four-line transects on each hill, running from the top of the hill to the shores of the lake and cutting across the three zones were demarcated. Trees were sampled within plots measuring 20 m x20 m ($400m^2$) placed at an interval of 200m, while shrubs and lianas were sampled in sub-plots of 10m by 10m nested in main plots in each of the three study zones along the predetermined line transects. The cover of woody plants was determined using a line intercept method. A 20m tape measure was systematically placed along the predetermined transects at an interval of 200m, and any woody plants intercepted by the tape were identified and intercept distance recorded for determination of basal cover. A total of 63 woody plant species belonging to 32 families and 51 genera were recorded, out of which 66.7% were trees, 31.7% shrubs and 1.6% lianas. The upper zones had significantly higher woody species diversity, species richness, and abundance than the middle and lower zones. A statistically significant difference was observed in both the density of trees and shrubs ($P<0.001$) among the three study zones. There was a significant difference in percent cover of shrubs ($p=0.010$) which increased upslope, with the upper zone of Wanyama hill recording a significantly higher ($P\leq0.05$) percent cover of shrubs (67.9±11.9). The lower zones depicted lower abundances of plants compared to the middle and upper zones. This was attributed to the various activities that

are carried out in the lower zones particularly clearing of woodland to give way for crop production and settlements. Sustainable land management practices such as planting more trees and protection of existing tree species in the lowlands and settlement areas is recommended for effective restoration of land cover of the study area.

Keywords: Woody plants; species diversity; plant density; Rusinga Island; cover; land-use.

5.1 INTRODUCTION

In many parts of the World, anthropogenic impacts exacerbated by those of climate change are the leading causes of loss of biodiversity (Foody and Cutler, 2003). Moreover, ineffective enactment of policies by national institutions intensifies losses of biodiversity in various countries since little attention is given to ensure that regulations are put in place and implemented for the management and conservation of natural resources (Abunie and Dalle, 2018). Most of the wild plant species are experiencing threats from overexploitation because only very few of them are cultivated and due to the ever-increasing extraction pressure (Schippmann et al., 2002). Woody plant species are seriously threatened in numerous parts of the World. In the tropics, 10% of all the plant species are estimated to be threatened with the highest rates recorded for woody plants (Tabuti, 2012). Diminishing vegetation cover and diminution of natural resources are usually coupled with shortages in food and drought that have become the main threats influencing the lives of millions of people (Brook et al., 2006). Decrease in vegetation cover has numerous effects like poor watershed protection, increased soil erosion with possible flooding and biodiversity losses resulting to variability in ecosystems and a reduction in the availability of goods and services (Gojamme and Tanto, 2016). Woody vegetation resources are invaluable in the provision of the various types of products (Sekhwela et al., 1992). They provide fodder for the livestock, source of firewood, construction materials, medicine, mulch and soil conservation (Brandt et al., 2016). The functions of woody plants in the provision of food, medicine, energy and shelter to the rural poor reduce some of the costs that the government would have incurred in providing these services and hence cash savings (Danda, 2014). Woody vegetation plays vital roles in safeguarding the environment and quality of life through the removal of pollutants, offsetting carbon emissions, shading and cooling (Gao et al., 2013). In drier areas of Africa trees and shrubs are an important source of fodder for livestock with trees generally browsed or lopped by both the domestic and wild animals (Abule et al., 2005). In Africa, it is estimated that 75% of trees and shrubs are used as browse plants and most of them being legumes (Mideksa et al., 2015). Despite their importance, the natural forests are diminishing under pressures of deforestation and other human interferences leading to land degradation causing Global environmental problems (UNCCD, 2003). The end results of land degradation on the biodiversity of plants are overwhelming where it distracts the distribution, species diversity and the floristic composition (Brooks et al., 2006) and the consequences are reduction in vegetation cover, resilience of key species and decreased species diversity (Kairis et al., 2015). The challenges of vegetation degradation can only be addressed if there are efforts to conserve and preserve the remaining vegetation resources and rehabilitation of degraded areas (Alelign et al., 2011).

Rural and marginalized communities depend heavily on woody plants species as a source of income and for subsistence (Marshall and Newton, 2003). For example, FAO, (2009) reported that several Africans still use charcoal and wood for their heating and cooking purposes due to unavailability of affordable sources of energy and only 7.5 % of the rural populace has electricity. Moreover, more than 90% of the households in rural areas in Kenya use fuel wood either as charcoal or firewood (Oduor, 2012). Increased poverty and rapid human population growth are considered as the most notable causes of the losses in woody plant species (FAO, 2009). These drivers compel the local people to; collect woody plant species at unsustainable rates and increase the cultivation of crops into habitats that were originally occupied by woody plant species (Augusseau et al., 2006). Woody plants are a source of important products that are valuable in the generation of income, subsistence, medicine among other uses. Their loss therefore, can lead to suffering among the local people who have traditionally relied on them to meet their needs (Shackleton et al., 2002). This is particularly true for women (Marshall and Newton, 2003) who take care of their families and they are the ones who normally collect firewood for cooking (Tabuti, 2012). Other threats to the woody plant species components involve factors such as change in habitats, introduction of new species, pollution and competition between both the wild species and the people for living spaces and other resources (Caldecott et al., 1996).

Human-induced interferences like selective logging of some plant species, conversion of forest land to cultivation fields, clearing of land for settlements and livestock overgrazing are usually regarded as the major causes of changes in habitats (Chown, 2010). Despite these, studies on the floristic composition and diversity especially in developing countries have been very few and where conducted the results are always contradicting (Chown, 2010). Whereas some studies have shown reduction in species richness in degraded forests (Addo-Fordjou et al., 2009; Parthasarathy 1999), others have reported increased species richness (Bongers et al., 2009; Molino and Sabatier, 2001; Senbeta et al., 2005). The reason for such discrepancies between the results is that the type, frequency and intensities of disturbances and the concerned ecosystem (Bongers et al., 2009) influence the impacts of various disturbances on biodiversity. Both empirical studies (Mishra et al., 2004; Senbeta et al., 2005) and theoretical studies (e.g. Connell, 1978) have suggested that the diversity of species increases at low disturbance levels. Therefore, given such differing results and taking into consideration the rising threats to biodiversity, an evaluation and documentation of the floristic composition and diversity of woody plants is important to be familiar with the present status and to facilitate the development of efficient and effective conservation measures.

Several studies have been carried out in diverse terrestrial ecosystems to assess the diversity, density and cover of woody plant species (DeFries et al., 2010; Sorecha and Deriba, 2017; Fisaha et al., 2013; Yineger et al., 2008; Alelign et al., 2007; Hundera et al., 2007) and all of them found varying results. However, no such analysis has been conducted on the floristic composition, diversity, density and cover of woody plant species of Rusinga Island in Lake Victoria, Kenya. Information on species diversity, density and cover of area is necessary for informed management in terms of economic value, regeneration capability and ultimately to sustainable conservation of biological resources (Sarka and Devi, 2014). The data obtained from such a quantitative inventory provides an invaluable reference for forest assessments and enhances our knowledge by the identification of ecologically, valuable species in addition to species of special concern.

Rusinga Island is an ancient historic area with numerous archaeological sites that have given the World fossils dating back millions of years and it is also a biodiversity hotspot due to its bountiful birdlife (Tryon et al., 2012). However, the Island is reported to be influenced by high human disturbances leading to land degradation with significant loss of biodiversity (Ketelaars, 2015). These factors lead to shortages in flora and the modification of the ecosystems in addition to biodiversity losses (Froumsia et al., 2012). Therefore, this study sought to determine the diversity and composition of woody plant species in Rusinga Island to understand the current status of species in the area and to inform on the most applicable and effective conservation measures for the area.

5.2 DATA COLLECTION AND ANALYSIS

The obtained data from the sampling points described in Chapter 3 were analysed using quantitative statistical tools and formulae to show some of the measures of biodiversity like species richness, composition, and evenness. Shannon-Wiener Diversity Index (*H'*) and Shannon's evenness index (J) were used to estimate species diversity and evenness respectively. The indices were selected and used in the analysis owing to their popularity, sample size sensitivity and discriminant ability. Shannon diversity accounts for both the evenness and abundance of the species present and gives more emphasis to rare species (Tolera et al., 2008) while Shannon's evenness index expresses distribution of species in a community or area.

The following Shannon-Weiner index formula (equation 5.1) was used to calculate the Alpha diversity of the area (Magurran, 2004).

$$H' = -\sum pi \log pi \text{ ....} \textit{Equation 5.1}$$

H' is the Shannon-Weiner index, $pi=ni/N$; ni is the number of individual plants present for species i, and N is the total number of individuals; log is the natural log of pi. The higher the H′ the higher the diversity of plant species and vice versa is true. The index varies between 1.5 and 3.5 but can surpass 4.5 in some exceptional cases (Kent and Coker, 1992). In any plant community, the index increases with an increase in richness and evenness of plant species.

Shannon's evenness index is presented as (equation 5.2):

$$(J) = \frac{H'}{In(S)} \text{ ....} \textit{Equation 5.2}$$

Where H' is Shannon's diversity index, S is Species richness (Total number of species in a study site or community). *In* is the natural logarithm of the number, which is the power to which the base must be raised to obtain a number. The value of Shannon's evenness index varies between 0 and 1(Help et al., 1998). With 1 meaning that all the species have the same abundance and signify complete evenness and 0 signify no evenness and nearly all the total flora is concentrated on only one species (Ifo et al., 2016).

Species richness was calculated using Margalef's diversity index (D) (equation 5.3) (Clifford and Stephenson, 1975) as follows:

$$D_{Mg} = \frac{(S-1)}{InN} \text{ ………………………………………………………………………. } \textit{Equation 5.3}$$

Where N = the total number of individuals in the sample and S = the number of species recorded. To determine the similarities between the different study zones and hills, Sørensen's coefficient (SC), was used (Sørensen, 1948) since it is used to demonstrate the level of similarities of vegetation in different plant communities or sites. The Sørensen's coefficient is also called quotient of similarity or index of similarity and measures the ratio of the common and unique species. Sørensen's coefficient was calculated using equation 5.4.

$$SC = \frac{2C}{A+B} \times 100 \text{ ………………………………………………….. } \textit{Equation 5.4}$$

SC is the Sørensen's coefficient; C is the number of common species that are present in community 1 and 2, A is the total number of species in community 1, while B is the total number of species in community 2. The higher the value of SC the higher the number of common species shared between any two given sites and vice versa.

The following formula (equation 5.5) was used to calculate the density of woody plants

$$Density\ of\ plants/ha = \frac{Total\ number\ of\ individuals\ of\ a\ species}{Area\ of\ a\ quadrat\ (plot)} \times 10000 \text{ ....} \textit{Equation 5.5}$$

The cover of woody plants was calculated using equation 5.6 below

$$Cover\ of\ a\ species = \frac{Distance\ of\ interception\ of\ a\ species}{Length\ of\ the\ line} \times 100 \text{ ....} \textit{Equation 5.6}$$

The frequency of woody plant species was calculated using the following formula (Equation 5.7)

$$Frequency = \frac{Number\ of\ plots\ in\ which\ a\ species\ occurred}{Total\ number\ of\ plots} \times 100 \text{ ………………} \textit{Equation 5.7}$$

Raunkiaer's frequency class distribution was used to determine the frequency ranges of species (Raunkiaer, 1934).

Table 5. 1: Raunkiaer's Frequency class distribution

Raunkiaer's Frequency class	Frequency Range
A	1-20%
B	21-40%
C	41-60%
D	61-80%
E	81-100%

Data obtained on Shannon's evenness and diversity index, species richness, number of individuals, density, frequency and cover were subjected to one-way analysis of variance (ANOVA) using GenStat statistical package (14^{th} edition) to determine the differences among the three study zones. The means were separated using Tukey's multiple comparison tests.

5.3 RESULTS AND DISCUSSIONS

5.3.1 Species composition

A total of 63 woody plant species belonging to 32 families and 51 genera were documented in all the 98 sampled plots. Trees, shrubs, and lianas were represented by 42 (66.7%), 20 (31.7%) and 1(1.6%) species, respectively. Out of the total woody plant species encountered 78% of them were indigenous species with the exotic species represented by 22%. Plant family Euphorbiaceae recorded the highest number of species (8 species) followed by Mimosaceae (7 species); Caesalpiniaceae (6 species); Sapindaceae (5 species); Anacardiaceae, Apocynaceae, Bignoniaceae, Capparidaceae, Combretaceae, Flacourtiaceae, Meliaceae, Moraceae, and Tiliaceae (2 species each), with all the other families being represented by a single species each (Figure 5.1). The higher number of species recorded by plant family Euphorbiaceae and Mimosaceae is attributable to their adaptation to arid and semi-arid conditions which is a typical of Rusinga Island. Rusinga Island is characterized by hot and dry climate relative to the rest of the country (Asinjo, 2014).

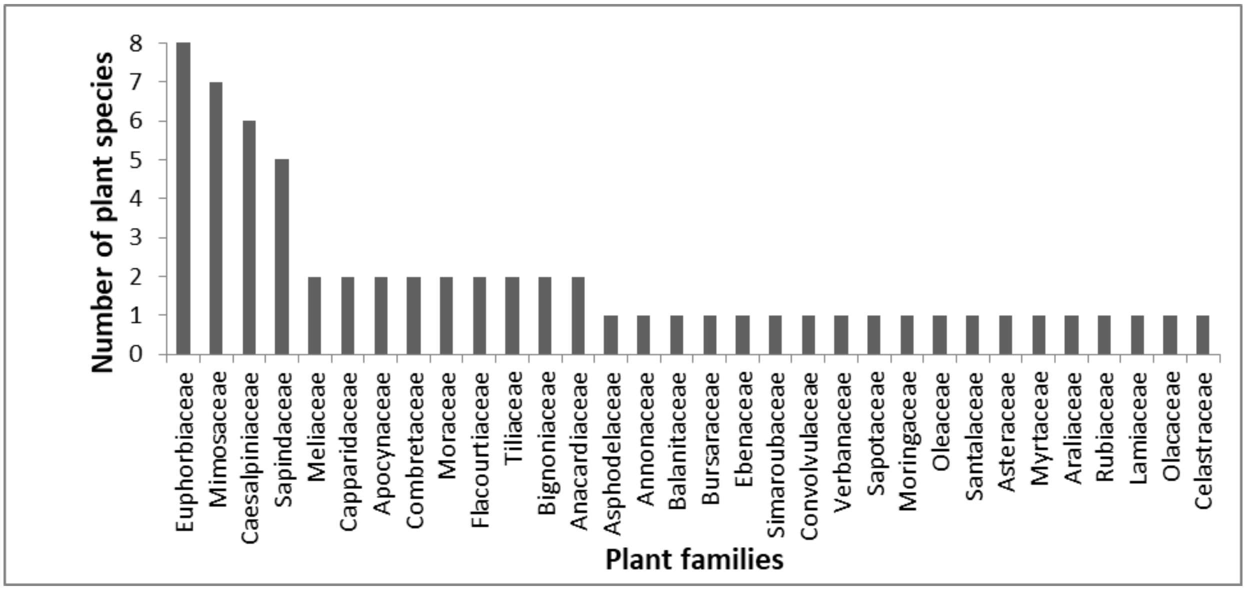

Figure 5. 1: Plant families encountered in the sampling plots

In all the three zones of all the hills the most common tree species were *Acacia seyal, Euphorbia tirucalii* and *Thevetia peruviana* whereas the most common shrubs were *Acalypha fruticosa, Harrisonia abyssinica, Ipomoea kituensis, Lantana camara* and *Psiadia arabica (*Table 5.2*).* There were some species confined to only one study zone of the hills. *Allophylus abyssinicus, Aloe volkensii, Commiphora africana, Grewia trichocarpa, Lanea schimperi, Olea africana, Osyris lanceolata*, *Pappea capensis*, *Synadenium compactum*, *Acacia brevispica, Euphorbia gossypina, Flacourtia indica, Phyllanthus guineensis* and *Tennantia sennii* were only recorded in the upper zones. Majority of the species were shared between the middle zone and the lower zone. The findings also showed that planted species were common in the lower and middle zones which included *Markhamia lutea*, *Senna siamea* and *Senna spectabilis.* Additionally, the number of species that were found in a study zone increased from the lower zone to the upper zone implying that most of the woody plants that were found in the lower zones were exotic and planted by the locals.

Table 5. 2: Percent woody plants species composition (Mean (%) ± SD) common in the three hills across the three zones in Rusinga Island

Plant form	Plant species	Study zones		
		Lower zone	**Middle zone**	**Upper zone**
Trees	*Acacia lahai*	NP	2±0.9	5±2.3
	Acacia seyal	3±1.8	10±7.2	2±0.5
	Allophylus abyssinicus	NP	NP	1±0.2
	Aloe volkensii	NP	NP	2±0.0
	Balanites aegyptiaca	NP	8±0.0	NP
	Commiphora africana	NP	NP	1±0.0
	Dodonaea viscosa	NP	1±0.0	7±0.0
	Eucleadivinorum	NP	2±0.0	10±5.3
	Euphorbia candelabrum	NP	1±0.0	3±1.5
	Euphorbia tirucalii	9±7.0	4±4.0	3±2.0
	Grewia bicolor	NP	1±0.1	4±3.8
	Grewia trichocarpa	NP	NP	1±0.0
	Laneaschimperi	NP	NP	1±0.0
	Leucaena leucocephala	2±0.0	NP	NP
	Markhamia lutea	4±3.4	2±1.1	NP
	Mimusops kummel	NP	NP	5±0.0
	Moringa oleifera	4±0.0	NP	NP
	Olea africana	NP	NP	7±0.0
	Osyris lanceolate	NP	NP	1±0.0
	Ozoroa insignis	NP	1±0.0	1±0.0
	Pappea capensis	NP	NP	2±1.2
	Senna siamea	6±2.1	3±0.8	NP
	Senna spectabilis	1±0.1	1±0.1	NP
	Synadenium compactum	NP	NP	1±0.0
	Thevetia peruviana	17±3.6	12±1.9	2±0.0
Shrubs	*Acacia brevispica*	NP	NP	3±2.6
	Acalypha fruticosa	20±4.7	25±11.3	16±18.1
	Carrisa spinarum L	NP	1±0.1	4±1.8
	Euphorbia gossypina	NP	NP	1±0.8
	Flacourtia indica	NP	NP	4±0.0
	Harrisoniaabyssinica	1±0.3	2±0.3	2±0.6
	Ipomoea kituensis	13±2.3	14±17.2	8±9.1
	Lantana camara	30±24.3	13±7.9	13±11.6
	Maytenus heterophylla	NP	1±1.1	4±0.6
	Phyllanthus guineensis	NP	NP	4±3.5
	Psiadia arabica	2±0.4	4±1.1	6±0.1
	Searsia natalensis	NP	2±0.6	9±1.3
	Senna bicapsularis	2±1.3	1±0.6	NP
	Tennantiasennii	NP	NP	2±0.0
	Tinea aethiopica	NP	3±0.7	9±5.6
Lianas	*Capparis fasicularis*	2±0.0	NP	NP

NP=Species not present

Data on the composition and diversity of plant species is essential for the management and conservation of natural ecosystems. In addition, availability of information on the floristic composition of a plant community is fundamental in understanding the general functions and structure of any ecosystem (Froumsia et al., 2012). In the current study, 63 woody plant species in total were encountered which comprised 66.7% of trees compared to shrubs (31.7 %), however this proportion of trees was composed of more small sized trees which were sprouting from previously cut tree stumps. Through personal observations, interviews with the community forest guards and the local people in the area it was revealed that most of the people always clear the vegetation for cultivable land expansion and to procure construction materials and for firewood. Information obtained from interviews with the local people revealed that *Olea africana* an indigenous tree species highly valued for construction poles and firewood was rare to be seen and the only few remaining species were found in some inaccessible parts of the upper zone of Ligongo hill. The reason for its disappearance was by overexploitation for the named uses. Alelign et al. (2007) in Ethiopia also stated that the highest number of plant species that were recorded in their study were made up of trees forming more than 56% compared to other growth forms. In contrast, Nie et al. (2019) reported that the highest number of plant species that were recorded in their study comprised of shrubs followed by trees and herbs.

The upper zones were found to have more species richness followed by the middle zones, the least species richness was detected in the lower zones, and the total number of species found in any of the three study zones increased from the lower zone to the upper zone. This was partially due to the activities that take place in different study zones thus causing the disappearance of woody species. For example, the lower zone is close to the shores of the lake and it is mainly characterized by farmlands where farmers tend to uproot most of the woody plants for ease of cultivation. The middle zone on the other hand is mostly characterized by human settlements and farmlands and it is dominated by exotic woody species, which are normally planted by the local people, and a few indigenous tree species which are retained in the farmlands. As reported by Hoekstra and Djinide (1988) some of the trees found in farmlands are not intentionally raised with cultivated crops but are maintained in the farms for other useful benefits like for shade to crops, fruits, building poles, firewood and medicine. The upper zones in this study area are mainly grazing areas, which are dominated by more shrubs and indigenous tree species. This zone is mainly used for grazing purposes and cutting of trees for firewood is prohibited and there is more emphasis by the local administration in collaboration with the Kenya Forest Service (KFS) on the conservation of the hilltops in the area as revealed by the interviews with the community forest guards and the local people. Ibrahim (2017) states that government regulations and the enactment of relevant forest laws play a very critical role in the conservation of an area. The results from the current study are comparable to the results of Sharma and Vetaas (2015) and Zimudzi and Chapano (2016) in Himalaya and Zimbabwe, respectively, who reported that species richness increased with rise in altitude from the low zones to the top zones. These trends were attributed to human disturbances as the main factors affecting the growth of trees. This is also analogous with other studies, which propose that species richness is persistently greater in areas with minimal disturbances such as forests and lesser in areas with high human activities such as farmlands (Okiror et al., 2012; Tabuti et al., 2009).

5.3.2 Species diversity, richness, evenness and abundance

The overall mean for Shannon's diversity index in all the study zones was 2.23. There was a significant difference in species diversity among the three study zones as determined by one-way ANOVA ($p=0.001$) (Table 5.3). Significantly higher ($p \leq 0.05$) species diversity was recorded (2.60) in the upper zone than in the middle zone (2.23) and the lower zone (1.87). The one-way ANOVA test revealed that there was no significant difference in species evenness among the three study zones ($p=0.203$).

Woody plant species richness varied significantly in the three study zones ($p=0.004$) with the upper zone recording significantly higher (3.86) species richness than the lower zone (2.27) (Table 5.3). The results also show a significant difference in the number of individuals recorded ($p=0.040$) among the three study zones.

Table 5. 3: Species diversity (H′), Shannon's evenness index (J), Species richness (D), and Number of individuals (N) in different study zones in the three hills in Rusinga Island

Attribute	Hills	Study zones			
		Lower zone	**Middle zone**	**Upper zone**	**P value**
Shannon's diversity index (H)	Ligongo	2.14	2.60	3.04	
	Kabade	2.25	2.51	2.88	
	Wanyama	1.21	1.59	1.89	
	Mean	**1.87^{a}**	**2.23^{b}**	**2.60^{c}**	**0.001**
Shannon's evenness index (J)	Ligongo	0.73	0.71	0.84	
	Kabade	0.78	0.76	0.84	
	Wanyama	0.75	0.59	0.67	
	Mean	**0.75**	**0.69**	**0.78**	**0.203**
Species richness (D)	Ligongo	2.86	4.89	4.84	
	Kabade	2.93	3.96	4.36	
	Wanyama	1.03	2.26	2.37	
	Mean	**2.27^{a}**	**3.71^{b}**	**3.86^{b}**	**0.004**
Number of individuals (N)	Ligongo	542	1932	1710	
	Kabade	330	706	968	
	Wanyama	49	490	860	
	Mean	**307^{a}**	**1043^{ab}**	**1179^{b}**	**0.040**

Values followed by the same superscript letter along the same row with the mean are not significantly different ($P \leq 0.05$)

Species diversity knowledge is imperative in establishing the influence of biotic disturbances, stability of the environment and the state of succession (Misra, 1989). The different indices of biodiversity are used to bring the diversity and abundance of species in different habitats to an equal scale for comparison and the higher the value, the greater the species richness (Naidu and Kumar, 2016).

The lower zones for all the hills recorded a lower species diversity of 1.87 compared to that of middle zone (2.23) and upper zone (2.60) and the diversity of species increased with increase in species richness. Overall, an average of 2.23 species diversity was recorded in all the hills and study zones. Since ecosystems with Shannon-Wiener values more than 2 are regarded as medium to highly diverse in terms of species (Giliba et al., 2011), this implies that Ligongo hill and the upper zones recorded the highest woody plant species diversity compared to the other hills and study zones and that Rusinga Island is a medium diversity ecosystem. These were attributed to the activities that are carried out in the lower zones like crop production and land use change thus high disturbance of the plants through clearing of vegetation for ease of cultivation. This study's results differ with the findings of Zimudzi and Chapano (2016) in Ngomakurira Mountain in Zimbabwe, who reported that the Shannon's diversity index for the bottom zone was higher followed by that of middle and top zones which they attributed to the differences in human disturbances. Song et al. (1997) reports that species diversity is affected by several factors for instance the ability of species to disperse into different areas, competition, geological conditions of the soils and environmental factors like temperature and solar radiation. These factors may affect the landscape and the structure of vegetation with substantial impacts on species richness and diversity (Heydari and Madhavi, 2009). According to Zegeye et al. (2006), species diversity and richness depend on the disturbance regimes by humans and the highest number of species are registered at low disturbance intensities while there is a severe decline at high disturbance intensities. In the current study woody species diversity increased from the lower zones to the upper zones of the hills meaning they were increasing with increase in altitude, on the contrary Montalvo (1993) found that species diversity decreased at all time with increase in altitude in the Mediterranean grasslands of Central Spain. However, in the Canadian mountainous region, Lee and La Roi (1979) found the contrary phenomena compared with Montalvo's study since plant species diversity increased along with altitude. Fu et al. (2010) reports that altitude is a key determinant of species composition on mountainous region since some environmental factors like temperature and edaphic factors always differ with altitude which impacts on the availability of water and characteristics of soils which end up affecting the performance of plants in terms of their growth. Occurrence of some specific plant species restricted to different strata supports the influence of altitude in shaping plant communities (Bhattarai and Vetaas, 2006).

Evenness is a measure of the homogeneousness of abundances in an area or a community. The upper zones recorded the highest species evenness (0.78) whereas the middle zone recorded the lowest evenness index (0.69) but no significant differences ($P \leq 0.05$) were recorded among the three study zones. The similarity in evenness across the study zones shows that the area is dominated by a few species. The lower species evenness recorded in the middle zone shows that there is an uneven representation and large difference in abundance of different species attributable to high human disturbance like clearing of land for settlement and for crop cultivation in addition to individual species characteristics and selective exploitation of some species as observed by Gebrewahid and Abrehe (2019). These results on species evenness corroborate those of Zimudzi and Chapano (2016) who reported that there was no significant difference in species evenness across the three zones on Ngomakurira Mountain in Zimbabwe. Even though their results partly contradict the current results since they found the top zone to have lower species evenness and higher species evenness at the middle zone. They attributed their findings to high disturbance factors in addition to variation in species ranges across elevational gradients. According to Bhattarai and Vetaas (2006), species ranges tend to narrow at the top while at middle altitudes there is an overlap maximising the number of species found in an area.

5.3.3: Similarity between plant communities in Rusinga Island

The highest similarity index (Least dissimilarity) of 79.41 % was recorded between the upper zones of Ligongo and Kabade hill (Table 5.4); this is because of the proximity of the two hills. On the other hand, the high dissimilarity (19.05%) between the lower zone of Wanyama hill and the upper zone of Ligongo hill may be due to lack of proximity to each other, differences in altitudinal range and species composition. The levels of anthropogenic impact may also have an effect as observed by Tilahun et al. (2011) in Menagesha Amba Mariam Forest in Ethiopia. In Taita hills of Kenya, Omoro et al. (2010) found higher similarities in species in sites that were close to each other and attributed to similar mechanisms of dispersing seeds and similar soil seed bank. Tilahun et al. (2011) reports that high similarities and dissimilarities are highly contributed by the closeness, effects of human activities and environmental factors such as the chemical and physical properties of the soil and the aspect of the slope on any plant community. The degree of similarity between plant communities allows combining them into an association of plant species (Srivastava and Shukla, 2016). According to Chao et al. (2006), communities having less than 65% similarities are regarded as dissimilar.

Table 5. 4: Percentage similarities of species in the three hills across the three study zones in Rusinga Island

		Wanyama			**Ligongo**			**Kabade**		
		Lower zone	**Middle zone**	**Upper zone**	**Lower zone**	**Middle zone**	**Upper zone**	**Lower zone**	**Middle zone**	**Upper zone**
Wanyama	**Lower zone**	1								
	Middle zone	40	1							
	Upper zone	27.27	43.75	1						
Ligongo	**Lower zone**	41.67	**58.82**	**50**	1					
	Middle zone	23.26	49.06	43.64	**59.65**	1				
	Upper zone	**19.05***	34.62	40.74	32.14	**61.33**	1			
Kabade	**Lower zone**	34.78	**66.67**	34.29	**70.27**	**53.57**	36.36	1		
	Middle zone	25	**61.9**	45.45	**69.57**	**73.85**	46.88	**62.22**	1	
	Upper zone	22.22	34.78	**54.17**	32	**55.07**	**79.41****	**36.73**	**51.72**	1

*Values in bold denote significant species similarities from 50%. * indicates the lowest similarity index, ** indicates the highest similarity index.*

5.3.4 Density and frequency of woody plant species

A statistically significant difference was observed in both the density of trees and shrubs ($P<0.001$) among the three study zones (Table 5.5). However, tree species recorded the lowest density in comparison to shrubs. These results show that the area is dominated by more shrubs than tree species. This can be associated with intensive and selective logging of trees for uses like construction purposes and firewood as reported by the community. Interferences caused by such activities impacts vegetation dynamics and the density of trees at both the local and regional levels (Hubbell et al., 1999) and are critical in shaping of plant communities (Sumina, 1994). Moreover, reduced number of trees has been ascribed to selective cutting down of larger trees (Kimaro and Lulandala, 2013). Similar results of higher density and dominance of shrubs reported by Bekele (1993) in the Central Plateau of Shewa, in Ethiopia and Fisaha et al. (2013) in Wof Washa natural forest in Ethiopia. Their findings were attributed to deforestation of large sized trees leaving only the small sized trees and shrubs and this high dominance of more shrubs is dangerous for the sustainability of any forest ecosystem (Fisaha et al., 2013). Similarly, Christie and Armesto, (2003) in Chile reported a very low density for a number of highly valued tree plant species economically prompted by poor micro-sites for regeneration and shortage of viable seeds. Scarcity and low density of several economically valuable trees is influenced by the degree and pattern of utilization and the abundance and the density of most tree species is quite poor (Aigbe and Omokhua, (2015).

Table 5. 5: Density and frequency of woody plant species in Rusinga Island

		Ligongo			Kabade			Wanyama			ANOVA (F2,35)
Attribute		**Lower zone**	**Middle zone**	**Upper zone**	**Lower zone**	**Middle zone**	**Upper zone**	**Lower zone**	**Middle zone**	**Upper zone**	**P**
Density(plants/ha)	Trees	860d	1477e	1114e	361b	434c	717d	163a	270ab	258ab	**<0.001**
	Shrubs	2842a	5423b	4074b	2200a	4257b	5563b	2325a	5600b	5563b	**<0.001**
	Lianas	25	25	25	0	0	25	25	0	25	**-**
Frequency (%)	Trees	54.2(19.3)	42.6(3.3)	51.3(7.5)	50.4(11.6)	54.0(15.8)	54.9(10.7)	62.5(25)	62.3(28.8)	60.4(28.4)	**0.916**
	Shrubs	72.4(9.3)	57.0(10.5)	59.9(9.8)	58.1(6.8)	69.1(10.0)	62.3(6.1)	75.0 (28.9)	70.6(17.2)	77.5(15.2)	**0.886**
	Lianas	8.3(0.0)	6.3(0.0)	3.6(0.0)	0.0	0.0	0.0	12.5(0.0)	0.0	16.7(0.0)	**-**

Means with different letters along the same row indicate significant ($P \leq 0.05$) differences

Overexploitation of indigenous plant species has altered numerous forests ecosystems in Kenya; therefore, many plant species are facing high risks of species extinctions and decline in population (Kiringe, 2005). Schleuning et al. (2011) reported that fragmentation of forests and selective logging of plant species are the two main causes of environmental change globally and alter biodiversity and environmental conditions in many tropical forests. Therefore, the lower density of different tree species noted in the study area can be associated with anthropogenic factor. The locals in general could also attribute the low density of trees and woody plants to the early harvesting of individuals at early growth stages.

There was no any significant difference in the frequency of all the woody plants among the three study zones (Table 5.5). However, the shrubs recorded a slightly higher frequency than trees. Frequency data indicates the evenness in the distribution of a species within an area and it is normally derived to inform on the presence or absence of a species in a certain community or area (Bonham, 2013). Woody plant species distribution in the different frequency classes indicated that the highest percentages of species were documented at the lower frequency classes with over 80% of the species having a frequency value below 40% (Figure 5.2). As indicated by Teketay et al., (2018) a higher frequency value of a certain plant species indicates a widespread distribution of the species in an area and thus its dominance. Tadele et al. (2014) in Zengena forest, Ethiopia, reported similar results of low frequency of most species. Variations in the frequency of species can be explained by preferences on certain habitats among species, adaptation characteristics of species, the level of disturbance, and availability of suitable conditions for regeneration (Shibru and Balcha, 2004). Additionally, Stephenne and Lambin, (2004) notes that human activities like changes in the degree of disturbance such as cutting of wood for firewood and for construction purposes may ultimately affect the rejuvenation of species and therefore the frequency decreases. The pattern depicted in the current study on the distribution of woody plant species within the frequency classes is not uncommon and may arise from human pressures principally on woody resources for energy and food.

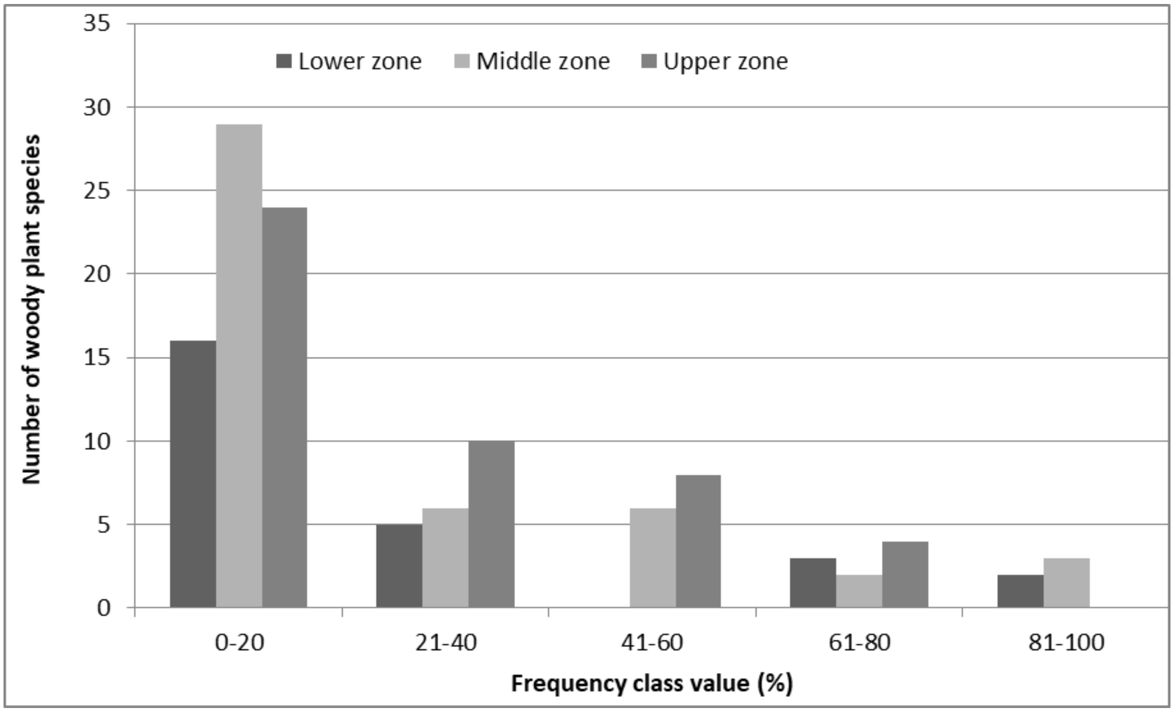

Figure 5. 2: Frequency class distribution of woody plant species in Rusinga Island

5.3.5 Cover of woody plant species in Rusinga Island

There was a significant difference in percent cover of shrubs (p*=0.010*) which increased upslope, with the upper zone of Wanyama hill recording a significantly higher ($P \leq 0.05$) percent cover of shrubs (67.9±11.9) (Table 5.6). A Tukey post-hoc test revealed significant differences for percent cover of shrubs between the lower and upper zones (*p*=0.008). However, the percent cover of trees did not differ statistically among the three study zones of all the three hills. The upper zones recorded higher percent cover of shrubs than the lower zones. This high percent cover of shrubs in the upper and middle zones could be attributed to clearing of land in the lower zones for crop cultivation and settlement. This shows that there is a reduction in the area covered by plants and that the cover of woody plants in the area is sparse. The decrease may also be as a result of rapid growth in human population revealed by the various human activities in the area like increased clearing of vegetation for arable farming and settlements. Sahoo and Davidar (2013) in India reported a declining condition of vegetation cover and their perceived causes. They reported unsustainable fuel wood extraction for domestic purposes among the main causes of degradation and severe loss of forests. On the contrary, Brandt et al., (2016); Hiernaux et al.,

(2009) observed an increase in woody plants cover and this was ascribed to changes in foliage density, canopy increment and woody population density.

Vegetation cover of an area has a specific composition and structure developed as a result of long-term interaction of both the abiotic and biotic factors (Peters, 1996). Jiang et al. *(*2017) reports that plants cover is the most noticeable resource that is significantly influenced by various anthropogenic activities like arable farming. Sanjari, (2006), reports that a decline in plants cover increases the effect of raindrops in decreasing water infiltration rates thus increasing the surface runoff and soil degradation. According to Gandapa (2017), the implication of the low crowdedness in an area designates that the surface is inadequately safeguarded from the unfavourable impacts of weather such as soil erosion, wind and heat that hampers the rejuvenation and growth of plants.

Table 5. 6: Percent cover (Mean ± SD in parentheses) of woody plant species in Rusinga Island

		Ligongo			Kabade			Wanyama			ANOVA (F2,35)
Attribute		**Lower zone**	**Middle zone**	**Upper zone**	**Lower zone**	**Middle zone**	**Upper zone**	**Lower zone**	**Middle zone**	**Upper zone**	**P**
Percent cover (%)	Trees	23.1(12.1)	21.1(12.2)	18.9(7.6)	20.4(8.1)	14.0(10.4)	10.2(4.2)	4.9(3.3)	28.7(14.5)	5.6(7.7)	**0.105**
	Shrubs	26.3(17.1) a	40.4(6.8) b	39.9(6.6) b	38.3(17.9) b	30.4(15.2) b	36.1(6.8) b	23.0(7.3) a	33.3(5.0) b	67.9(11.9) c	**0.010**
	Lianas	-	-	-	-	-	3.00	-	-	4.00	**-**

Means with different letters along the same row indicate significant (P≤0.05) differences

5.4 CONCLUSIONS AND RECOMMENDATIONS

The lower zones of all the hills recorded a lower species diversity, species richness and abundance compared to the middle zone and upper zones and the number of species found in a study zone increased from the lower to the upper zone. Only very few plant communities showed high species similarities with majority of them being dissimilar. Tree species recorded the lowest density, cover and frequency implying the predominance of more shrubs. This indicates that the larger trees were subjected to severe pressure due to intensive and selective logging of trees for different uses like construction purposes and firewood. These findings are imperative for monitoring of some species whose frequency may change markedly from year to year. As a result of the present study, restoration of ecosystems, sustainable use and conservation of woody plant species are recommended. In addition, tree species with a fast growth rate can be planted to form a regular source of firewood and in so doing lessen the pressure exerted on the existing natural forests. Awareness creation to the local inhabitants on the significance of woody plant resources and ecological consequences of deforestation is also recommended. Control of extensive overexploitation of woody plant resources (wood fuel in particular) is recommended by this study. Sustainable land management practices such as planting of trees and protection of existing tree species in the lowlands and in around settlement areas are recommended for effective restoration of land cover, as evidenced in highly disturbed areas with low plant cover within the lowlands and settlement areas than in less disturbed areas of the middle and upper zones. The lower species diversity, abundance and species richness in the lowlands and around settlements calls for the promotion of agroforestry practices through planting of multipurpose trees for enhanced ecosystem services.

CHAPTER SIX

6.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

6.1 General conclusions

The community in Rusinga Island has a rich knowledge of the condition and trend of their environment and is able to relate the observed changes in vegetation to specific factors, chiefly land use activities. The study has documented that the vegetation of Rusinga Island is highly deforested and dispersed and that all the forest trees are declining in abundance. The inhabitant community will influence the conservation of biodiversity in Rusinga Island. Thus, any conservation strategies, measures or interventions must seek the participation of the local community. The community in the study area prefers planting of trees, protection of existing trees, use of alternative sources of fuel, increased awareness creation on environmental conservation and controlled livestock grazing to reverse the observed changes. Generally, Rusinga Island is a medium diversity ecosystem. The lower zones recorded a lower species diversity, species richness and abundance compared to the middle zone and upper zones and the number of species found in a study zone increased from the lower to the upper zone. Felling of trees to pave way for cultivation is the main cause of low species diversity recorded in the study area, as evident in the lower zones where settlements and farms are located. Despite the low woody species cover, especially in the lower zone, there is an indication of recovery manifested in the dominance of saplings in the study area but their growth is hampered by uncontrolled livestock grazing. The dominance of more shrubs than tree species in the area is a manifestation of selective logging of trees for construction, charcoal production and firewood.

6.2 Recommendations

To ensure sustainable development, availability of resources to the present and future generation and to improve the natural diversity in Rusinga Island the following initiatives are recommended:

- The community should look for different sources of energy and use of energy saving stoves instead of relying heavily on firewood as a source of energy, which is the primary cause of the high deforestation reported in the area. In addition, fast growing and self-regenerating trees should be planted in the area to provide a sustainable and regular source of firewood and construction materials thereby lessening the pressure exerted on the remaining indigenous plant species.
- To avoid overgrazing proper grazing management should be adopted by the local community by reducing the stocking rate of livestock. Uncontrolled grazing of livestock that wander throughout the Island especially during the dry season should be avoided to boost the germination capacity of seeds and growth of woody plant species.
- Agroforestry practices through planting of multipurpose trees in the lowlands, settlement areas and forests should be encouraged through the supply of seedlings of both the indigenous and most preferred exotic plant species.
- Some of the most preferred species for reforestation like *Markhamia lutea, Senna siamea, Leucaena leucocephala, Olea africana* and *Euclea divinorum* should be promoted in the study area.
- To avoid soil erosion which is one of the main causes of changes in vegetation in the area, construction and maintenance of terraces and other soil conservation structures through mobilizing the local people to carry out the activities together and providing the appropriate incentives is recommended.
- Since this study focused on the woody plant species only, studies on the herbaceous plant species diversity and composition are recommended.

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APPENDICES

Appendix 1: Questionnaire guide for the study

<u>Questionnaire to assess perceptions of the local community on the changes in vegetation composition and abundance in Rusinga Island</u>

1.0 General information

1.1 Date of interview: …………/…………/… ………

1.2 Questionnaire serial number: …………/………/..............

1.3 Name of enumerator: ………………………..…………………………

1.4 Sub-County……………………Ward…………………Sub-location………………Village………………….

Respondent's information

1.5 Name of respondent: ……………………………………………….............................

1.6 Sex: (1) Male………………………… (2) Female…………………………………..

1.7 Age: (1) Under 30 years………….(2) Between 31 – 60 years…………...3) Over 60 years…………………………………

2.0 Household's information

2.1 Household head: (1) Male…………………(2) Female ………….Age....................

2.2 Household Size/ Composition: no of males ....no of females............Total…………….

2.3 Education: (1) None……(2) Primary…..(3) Secondary......(4) Post-Secondary …………

2.4 Number of children going to school……………………………........

2.5 What is your main occupation? ....

2.6 Which is your Main source of livelihood..?

2.7 Please list all the income generation activities and how much you get from each per month?

Source of income	**Rank (1, 2, 3,4,5)**	**Last wet season amount (KES) per month**	**Rank (1, 2, 3,4,5)**	**Last Dry season amount (KES) per month**
Crop production…………				
Livestock production………				
Beekeeping……….				
Business……….				
Formal employment……….				
Fishing…………				
Others				

2.8 Are you employed? Yes……… No……….

2.9 If yes, how much do you earn per month? ………………………………….

2.10 Is there any other member of your family in the formal employment? Yes……. No……

2.11 If yes, do you receive any remittances from them? Yes………No………

2.12 If yes, how much do you receive as remittance per month?...................................

2.13 Land tenure system: Clan/family ownership…………. Old titled private land………. Newly titled private land…………Squatter……………. Scheme settlement………….

2.14 How much land do you own? ....acres.

2.15 Have you received any training in environmental management? Yes……. No…………….

2.16 If yes, fill table below;

Type of training/Topic	Organization provided the training	Year of training	Cost (KES) involved	Frequency of training in a year

2.17 Have the trainings you have received changed your perception on environmental care and management? Yes………. No………….

2.18 Since you received the training, how many trees have you planted? In your compound/farm…………………. Elsewhere……………

2.19 (a)What do you use for cooking/heating in your household?

Type of energy	Source	Cost (KES) involved/month
Kerosene [ ]		
Firewood [ ]		
Agro-waste [ ]		
Gas [ ]		
Charcoal [ ]		

2.19 (b)What are the main reasons/motivation for using the type energy in (a) above in cooking/heating?

i) Easily available……………

ii) Less expensive…………….

iii) Environmentally friendly………….

iv)Higher energy content………….

v) Others (Clarify) ………………….

2.20 Do you use firewood in your homestead for cooking? Yes……. No….

2.21 If yes, where do you get them from?

i) Own land…………

ii) Neighbours land………….

iii) Hills/Forests…………….

iv) Others (*please specify*) ……………………………

2.22 If from the hills/forests, what is the distance from your home to the hills/forest ....Kilometres

2.23 Who collects the firewood in your household?..

2.24 What kind of firewood do you get for use?

i) Dry and dead wood……………….

ii) Cutting live trees……………….

iii) Cut branches …………………….

2.25 Which are your five (5) favourite trees for firewood and why? (*Rank them according to the order of preference with the most preferred species given a value of 1*)

Tree species	**Reason for preference**
1.	
2.	
3.	
4.	
5.	

2.26 Do you have a woodlot in your compound? Yes………No……….

2.27 Do you have a tree nursery in your compound? Yes………No………

2.28 If yes, where did you learn how to establish one?

i) …………………………………………………………………………

ii) ………………………………………………………………………..

iii) ………………………………………………………………………..

iv) ………………………………………………………………………….

2.29 Where do you source the seeds? Buying………. Gathering ………. Neighbours ……… Others …………

2.30 If buying, from where ……………………… and at what cost/kg…………………

2.31 Have you planted or participated in tree planting activity as an individual or group Yes………No………?

2.32 If yes above, where do you get the seedlings from?

i) ……………………………………………………………………………

ii) …………………………………………………………………………..

iii) …………………………………………………………………………..

iv) ……………………………………………………………………

2.33 Which tree species do you plant and reasons for your choice?

Tree species	**Reason**
1.	
2.	
3.	
4.	
5.	

2.34 Where do you plant the seedlings?

i) Farm…………….

ii) Homestead………….

iii) Others (*Please describe*) ……………………………………………

2.35 What would you say of sourcing firewood ten years ago?

i) Easy……………………………………………………………………

ii) Somewhat difficult…………………………………………………………………….

iii) Difficult……………………………………………………………………

iv) Other………………………………………………………………………….

2.36 What would you say of sourcing firewood at present?

i) Easy…………………………………………………………………………

ii) Somewhat difficult……………………………………………………………….

iii) Difficult………………………………………………………………….

iv) Others (Please specify) ……………………………………………………………………

2.37 What do you think should be done to ensure you have enough supply of firewood in future?

i) ……………………………………………

ii) ………………………………………………….

iii) ……………………………………………

iv) …………………………………………………….

2.38 Do you use charcoal for cooking or heating? Yes……No…….

2.39 If yes, where do you get the charcoal from?

i) Burning your own…………….

ii) Buying………………..

2.40 If burning, where do you source the wood for burning charcoal (List)

i) ……………………………………………

ii) ………………………………………………….

iii) ……………………………………………

iv) …………………………………………………….

2.41 Do you get licenses/permission to burn charcoal? Yes………No…………

2.42 If yes, from who?

i) Forest officers ………….

ii) County government……….

iii) Police…………….

iv) Others (*Please specify*) ………………………………………………

2.43 If buying charcoal, from where…………………… and how much per bag/*debe/Gologolo* Kshs……………………

2.44 For how long have you been getting charcoal from your current source………………….

2.45 Do you see yourself sourcing charcoal from the same source in the next 3 years?
Yes……. No……………

2.46 If no, what do you think should be done to ensure you have enough charcoal supply in future?

i) …………………………………………………………………………

ii) ………………………………………………………………………..

iii) ………………………………………………………………………..

iv) ……………………………………………………………………….

v) ……………………………………………………………………….

2.47 Do you prefer charcoal from any particular tree species? Yes………. No……………

2.48 If yes, which tree species (*Rank according to the order of preference with the most preferred tree species given a value of 1*)?

Name of tree species	**Reason for preference**	**1=Indigenous** **2=Exotic**
1.		
2.		
3.		
4.		
5.		

2.49 What would you say of sourcing charcoal ten years ago?

i) Easy…………………………………………………………………………

ii) Somewhat difficult…………………………………………………………

iii) Difficult……………………………………………………………………

iv) Other……………………………………………………………………….

2.50 Which tree species are important for the following uses?

Construction and fencing	Firewood	Charcoal making	Medicine	Livestock feed

2.51 Which tree species are used as livestock fodder and which parts are fed on the livestock?

Tree species	Plant parts

3.0 Vegetation changes

3.1 Do you think there has been change of woody vegetation composition and abundance over time? Yes………. No……….

3.2 If yes, where has the change occurred?...

3.3 Have you seen any negative or positive changes on vegetation composition and abundance in this area? Yes……. No……….

3.4 If yes, what changes have you seen?

Negative changes	**Positive changes**

3.5 What are the causes of the changes seen?

i) …………………………………………………………………………

ii) ………………………………………………………………………..

iii) ………………………………………………………………………..

iv) ……………………………………………………………………….

v) ……………………………………………………………………….

3.6 Are there any efforts by community to address the changes in vegetation? Yes…….
No……….

3.7 If yes, which interventions.

i) …………………………………………………………………………

ii) ………………………………………………………………………..

iii) ………………………………………………………………………...

iv) ……………………………………………………………………….

v) ……………………………………………………………………….

3.8 If no, why?

i) …………………………………………………………………………

ii) ………………………………………………………………………..

iii) …………………………………………………………………………..

iv) ………………………………………………………………………….

v) ………………………………………………………………………….

3.9 How can the changes be addressed by the Community, Households, County government and National government?

Households	**Community**	**County government**	**National government**

3.10 Are there any invasive tree species in Rusinga Island? Yes……. No………

3.11 If yes, which ones

i) ……………………………………………………………………………

ii) …………………………………………………………………………..

iii) …………………………………………………………………………..

iv) ………………………………………………………………………….

v) ………………………………………………………………………….

3.12 Are invasive species a threat in Rusinga Island? Yes………. No…….

3.13 If yes, which threats and which conservation measures can be adopted to address them

Threats	Conservation measures

THANK YOU FOR YOUR TIME!!!!!!!!!

Appendix 2: Interview guide for Key informants

KEY INFORMANT INTERVIEWS

ASSESSMENT OF THE LOCAL COMMUNITY PERCEPTIONS ON THE CHANGES IN VEGETATION COMPOSITION AND ABUNDANCE IN RUSINGA ISLAND

Section 1: General Information

Date of interview: ……/………. /……… Name of enumerator: ……………….……………….

County……………….……… Sub-county……………….……. Location…………………………

Sub-location……………….……Village………………………………….

Name of respondent (optional)…………………………Gender: i) Male [ ] ii) Female [ ]

Age of the respondent …………………… Education level: i) None [ ] ii) Primary [ ] iii) Secondary [ ] iv) Post-Secondary [ ]

Section 2: Woody plant use

1. List all the woody species that were found in Rusinga Island 30 years ago and at present (scientific, common and local names) and their uses.
2. Rank the most important woody plant species for? Construction, fencing, firewood, medicine, charcoal making, and other uses.
3. Which tree species are used as livestock fodder and which parts are fed to the livestock?
4. Mention rare or abundant woody plant species

Section 3: Vegetation change

1. Do you think there has been change of woody vegetation composition and abundance over time? What changes have you seen both positive and negative changes.
2. Has vegetation changed over the past years from?

   i. Grassland to woodland [ ]

   ii. Woodland to grassland [ ]

   iii. Others (*please explain*) ……………………….

   Where has the change occurred?...
3. What are the causes of the changes seen?
4. Are there any efforts by the community to address the changes in vegetation?
5. How can the changes be addressed by 1. Households 2. Community, 3. County government,

4. National government?

6. Mention woody plant species perceived as increasing, decreasing or stable in abundance/ availability for the last 30 years and give reasons for the observed trends (*Rank the reasons in order of importance*).
7. What do you think are the major threats to the plants of Rusinga Island and the most appropriate measures to conserve them? (*Rank the threats according to the order of importance with the most severe threat given a value of 1*)

Section 4: Reforestation program

1. Would you prefer a wooded area?
2. Which species can be used for reforestation of degraded areas in Rusinga Island?
3. Rank top three most important/useful species and three least preferred species for reforestation.
4. Would you support indigenous woody species reforestation program? i) Yes [ ] ii) No [ ]
5. If yes, name the indigenous tree species and give reasons (*Rank them according to the order of preference with the most preferred species given a value of 1*)
6. List most preferred exotic tree species and why?
7. List most protected indigenous woody plant species and why?
8. Are there regulations on cutting trees, are they enforced? And who enforces them?
9. Are there any invasive tree species in Rusinga Island? And which ones are they?
10. Which threats are brought by the invasive species and which conservation measures can be adopted to address them?
11. Please tell me about tree planting in Rusinga Island? Which tree species are mostly planted and why?

Appendix 3: Focus group discussion guide

FOCUS GROUP DISCUSSION CHECKLIST

Aim: To obtain shared perceptions among groups on the use and status of woody plant species in Rusinga Island.

Focus group areas: Two focus groups in each location i.e. Rusinga east and Rusinga west**.**

Section 1

1. List all the woody species that were found in Rusinga Island 30 years ago (*eldest people in the group to list)* (scientific, common and local names) and their uses.
2. What about now? Do they still exist?
3. How many people here have a tree nursery? Where did you learn how to establish one? Where do you source the seeds? Who are your customers? Where do you plant the seedlings?
4. Have you received any training on environmental management?
5. Have the trainings you have received changed your perception on environmental care and management? Since you received the training, how many trees have you planted? In your compound/farm………………….; Elsewhere……………
6. Do you have a woodlot in your compound? Are there any benefits obtained from your woodlot?
7. Have you planted or participated in tree planting activity as an individual or group? Where do you get the seedlings from? Are they enough? Which tree species do you plant and reasons for your choice?
8. What do you use for cooking/heating in your homesteads? What are the main reasons / motivation for using the type of energy for cooking /heating?
9. What would you say of sourcing firewood/charcoal ten years ago and at the present? What do you think should be done to ensure you have enough supply of firewood/charcoal in future?

Section 2: Woody plant use

1. Rank the most important woody plant species for; Construction, fencing, firewood, medicine, charcoal making, and other uses.
2. Which tree species are used as livestock fodder and which parts are fed to the livestock?
3. Mention rare or abundant woody plant species

Section 3: Vegetation change

1. Do you think there has been change of woody vegetation composition and abundance over time? What changes have you seen both positive and negative changes.
2. Has vegetation changed over the past years from?

   i. Grassland to woodland [ ]

   ii. Woodland to grassland [ ]

   iii. Others (*please explain*) ……………………….

   Where has the change occurred?..
3. What are the causes of the changes seen?
4. What are the environmental challenges from the changes seen to the community livelihoods?
5. Are there any efforts by the community to address the changes in vegetation?
6. How can the changes be addressed by 1. Households 2. Community, 3. County government, 4. National government?
7. Mention woody plant species perceived as increasing, decreasing or stable in abundance/ availability for the last 30 years and give reasons for the observed trends (*Rank the reasons in order of importance*).
8. What do you think are the major threats to the plants of Rusinga Island and the most appropriate measures to conserve them? (*Rank the threats according to the order of importance with the most severe threat given a value of 1*)

Section 4: Reforestation program

1. Would you prefer a wooded area?
2. Rank top five most important/useful species and five least preferred species for reforestation and why?
3. Would you support indigenous woody species reforestation program? Name the indigenous

tree species and give reasons (*Rank them according to the order of preference with the most preferred species given a value of 1*)

4. If prefer exotic species, name the woody plant species and give a reason for their preference.
5. List most protected indigenous woody plant species and why?
6. Are there any regulations on cutting trees, are they enforced? And who enforces them?
7. Are there any invasive tree species in Rusinga Island? And which ones are they?
8. Which threats are brought by the invasive species and which conservation measures can be adopted to address them?
9. Please tell me about tree planting in Rusinga Island? Which tree species are mostly planted and why?
10. What would you say about the status of vegetation cover, composition and abundance in Rusinga Island?