SPATIAL-TEMPORAL CHANGES OF LANDCOVER TYPES IN RESPONSE TO ANTHROPOGENIC DYNAMICS IN YALA SWAMP, SIAYA COUNTY, KENYA

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2016
DECLARATION

Declaration

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

......................................                                                ......................................

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DEDICATION

This work is affectionately dedicated to my loving parents Mr. and Mrs. Ondere for their support, love and encouragement throughout my study period. I love you Mum and Dad
ACKNOWLEDGEMENT

To the most High God be glory great things He has done. I acknowledge your
great provision, protection and support throughout the duration of this course. My
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<tr>
<td>CVA</td>
<td>Change Vector Analysis</td>
</tr>
<tr>
<td>ERDAS</td>
<td>Earth Resource Data Analysis Software</td>
</tr>
<tr>
<td>ETM</td>
<td>Enhanced Thematic Mapper</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographical Information Systems</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>HAO1 or 2</td>
<td>Null Hypothesis 1 and 2</td>
</tr>
<tr>
<td>IUCN</td>
<td>International Union for Conservation of Nature</td>
</tr>
<tr>
<td>ICRAF</td>
<td>World Agroforestry Centre</td>
</tr>
<tr>
<td>KNBS</td>
<td>Kenya National Bureau of Statistics</td>
</tr>
<tr>
<td>KWS</td>
<td>Kenya Wildlife Service</td>
</tr>
<tr>
<td>LANDSAT</td>
<td>Land Resource Satellite</td>
</tr>
<tr>
<td>MEA</td>
<td>Millennium Ecosystem Assessment</td>
</tr>
<tr>
<td>NMK</td>
<td>National Museums of Kenya</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>RCMRD</td>
<td>Regional Centre for Mapping of Resources for Development</td>
</tr>
<tr>
<td>RS</td>
<td>Remote Sensing</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>UNEP</td>
<td>United Nations Environment Program</td>
</tr>
<tr>
<td>UTM</td>
<td>Universal Transverse Mercator</td>
</tr>
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<td>UN</td>
<td>United Nations</td>
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ABSTRACT

Research in wetlands has made great progress and it is widely recognized globally that they are under threat of disappearing and degradation due to overexploitation of their products and services. The study was undertaken in Yala wetland that covers an area of 17,500 ha in an area with one of the highest population density and growth rate in Kenya. The wetland is mainly cleared for crop cultivation and settlement and about 2,800ha (Figure 4.14) have been drained for commercial agriculture. It is therefore important to characterize the composition of land cover before any conservation and management programs are put in place. The main aim of this study was to analyse, identify, characterize and examine associated spatio-temporal land use changes linked to anthropogenic activities in the wetlands and its environs from satellite imagery, the information will be used to develop and come up with land use/cover maps to aid in sustainable management and utilization of the Yala wetland resource. Geographic Information systems (GIS) and Remote Sensing were employed to achieve this objective, LANDSAT ETM for 1990, 2000, 2010 and 2014 satellite images were used. Image analysis was done in Arc GIS 10.1 and ERDAS 9.3 software packages. Based on GIS and RS analysis, it was evident that the study area has undergone major changes. The size of the wetland had reduced by 33 % over the 25 year period, and agricultural land had increased by over 65%, lake area reduced by 7%, shallow waters reduced by 7%, settled area increased by 50%, rice paddies increased by 21 % open grasslands with shrubs on the other had reduced by 83%. This could be attributed to increase in population at 65% 1989 and 2009 census of Kenya. Field studies indicated that burning of the wetland at 41%, uprooting of wetland vegetation 14% and cutting of the wetland vegetation at 32% are the main methods used to clear the wetland for farmland and settlements. Though the residents engage in other economic activities the most preferred one is mat making at 29% mainly dependant on papyrus reeds. Land ownership is also contributing to low sustainable measures being undertaken; the field survey indicates that 42% of the respondents are managing family land while 40% have inherited making it hard to easily implement conservation measures in the wetland. SPSS T-test was run for both null hypothesis HAO1; there are significant spatial and temporal changes in land cover types due to land use changes in the Yala wetland over the study period was 0.9223 and HAO2; spatiotemporal characteristics of population growth in the study area have direct linkages on land use land cover changes in the Yala wetland was 0.9126, the results were accepted. In conclusion, it was realized that the Yala swamp wetland has increasingly been faced with serious problems especially human interference leading to degradation and overexploitation of its resources thus the continuous reduction of the wetland size. Sustainable measures such as development of the tourism and papyrus industry, aquaculture practice and better policy implementation should therefore be undertaken to ensure its resources are used sustainably and promote coexistence with the growing human population.
CHAPTER ONE
INTRODUCTION

1.1 Background

Wetlands as ecotone systems between both terrestrial and aquatic landscapes are universally known to be among the most productive ecosystems of the Earth (Dugan, 1993; Mitsch and Gossellink 2000). They have high potential for all season agricultural activity that provides both food and income as well as a wide range of other ecosystem services for riparian communities (Millennium Ecosystem Assessment Report 2005; Barbier et al., (1998) and Dobiesz and Thompson., (2009) have all compared wetlands to “the kidneys of the landscape”, because of the functions they perform in the hydrological and chemical cycles, and as “biological supermarkets” because of the extensive food webs and rich biodiversity they support.

In the last three decades, wetlands have received much attention worldwide because of their decline leading to a decline in the provision of ecosystem goods and services. Wetland biodiversity resources are under threat of human activities resulting in erosion and loss of biodiversity. It is estimated that over 50% of world wetlands have been lost since the 1950s as a consequence of the human activities (Millennium Ecosystem Assessment Report, 2005). However, the role of these activities in the dynamics of wetland ecosystems is not clearly understood even as
their quantities and spatial spread continues to dwindle (Dugan 1993; Dobiesz et al., 2009). In Africa for instance, the percentage of wetland area as estimated by is about 1% to 16% of the total area of the continent. With a situation believed to be worsening, these estimates could be much lower as the ecosystems continue to dwindle in many parts of the developing world (the Millennium Ecosystem Assessment Report, 2005; Hughes and Hughes, 1992; Spiers, 1999).

On the Kenyan portion of the Lake Victoria, these wetlands cover an extensive area and support a wide range of economic activities that sustain a significant proportion of the population of western Kenya (Kairu, 2001). The interdependence and importance of these wetlands is graphically expressed in the fact that the plant and animal material produced on land and in the wetland is exported into the Lake. They become food for fish and crustaceans and is the basis which are commercial and recreational fishing. Furthermore, the wetlands support a rich array of birds that inhabit the lake throughout the year. They also provide physical stability to the shores besides performing critical filtration functions for Lake Victoria which is presently facing a major threat of pollution from land based human activities.

The study area, the Yala wetland, is a part of the Lake Victoria wetlands complex that is shared resource between Siaya and Busia counties. It is the largest wetland ecosystem in the basin estimated to cover an area of 17,500 h (Hues and Hues,
During the last half of the century or so, this wetland and the livelihoods it sustains are becoming more and more threatened and their ecological integrity are jeopardized by several anthropogenic factors—which include land use, increased human population and the relations between lake/water level dynamics and these anthropogenic factors. As in many other places in the world, this sort of situation has created multiple stresses leading to the degradation and loss of these ecosystems (Davis, 2010).

In order to address this rapidly evolving scenario, a thorough understanding of both the external drivers and internal ecosystem dynamics is required. This should encompass a good knowledge of the interactions between them as well as the traditional uses and changing socio-economic factors that are forcing the non-traditional uses, at appropriate spatial and temporal scales (Davis et al., 2010; Kareri, 1992;). However, even though the Yala wetland and its surroundings is believed to be under great pressure from anthropogenic drivers, accurate data and information necessary to design mitigation and management measures is still scarce (Grabowsky and Poort, 1987; Kairu 2001).

1.2 Statement of the Problem
In the past, wetlands were considered as ‘waste land’, and a source of disease like malaria and needed to be transformed into more useful purposes. This attitude led to reclamation of wetlands for agriculture, and settlement. They continued reducing in sizes as modern techniques of draining made them even more
attractive for agriculture and their location, for instance, in the coast, makes them the perfect site for construction of harbours and large plants and for waste disposal.

In recent past, the importance of wetland ecosystems was recognized internationally which led to the Convention of Wetlands of National Importance in 1970 in Ramsar, Iran. Kenya ratified the Ramsar Convention in 1990 and has designated 5 sites as wetlands of national importance. These sites which include lakes Baringo, Bogoria, Nakuru, Elementaita and Naivasha. The Kenya Wildlife Service (KWS) and the National Museums of Kenya (NMK) are the implementing bodies of the convention. Unfortunately, the Yala Swamp is not amongst the 5 protected wetlands. Which has left it vulnerable to abuse and overuse of its resources by a multitude of stakeholders with different interests.

Yala wetland is facing a major threat of degradation due to anthropogenic and hydrodynamic driving forces which could disrupt the environmental balances, irreparably destroy the wetland and affect the livelihood of the riparian communities who benefit from the resources of the ecosystem. The natural landscape of the wetland is rapidly being converted to agricultural land use and most of which involve destruction of indigenous wetland cover types. Furthermore, population dynamics in the administrative units, which is believed to be a critical driver of these land use conversion is rapidly changing and is
expected to continue into the future. However the characteristics of the population that drive these changes even as the population itself increases are yet to be clearly understood. If they are not well understood, it design of sustainable management measures will not be attainable and this causes a major threat to the existence of the Lake Victoria wetland ecosystem.

1.3 Justification of the study

Wetlands are very important in the environment and therefore a degraded wetland would negatively affect the environment by affecting the ecosystems services it offers (Abila, 2002). Furthermore, an increasing rate of sediment deposition has been observed in the Lake Victoria over the last 100 years. This is attributed to increased agricultural activities that encourage de-vegetation and reductions in wetland cover in the basin (Awange and On’gan’ga, 2006). However, the spatial extent of the land use change is essential in establishing the rapidity and direction of the changes taking place in the wetland is with the increasing human population and precarious climate change threats leading to a recession of the lake levels, it is expected that these trends will continue into the future. For instance, it is feared that wildlife that was once endemic to the wetlands (i.e Tragelaphus Spekii commonly known as Sitatunga) is continuing to disappear while grain eating birds such as the Ploceidae spp seem to be on the increase indicating changes in the habitats (Barbier, 1994).
However, data and information on the spatial and temporal characteristics of these driving processes, and how they relate with the degradation activities going on in the wetland are scarce (Abila, 2002). Consequently, the continued, degradation and destruction of the integrity the wetlands by reducing their size and ability to effectively perform its function is a matter of concern. Studies that will lead to suitable management measures being put in place to abate further destruction are required. The study will identify and document spatial temporal ecological processes and socio-economic factors mechanisms that influence the identified threats.

Remote sensing and GIS use tools to determine and link social systems to ecological systems using techniques such as, the study will fill the gap between technical systems and social systems. This is an area that has been inadequately addressed by most past studies. The information generated which will include land use/biotic cover type change maps spatial and temporal change, population increases and spread and their interactions. Information will be useful in designing effective and sustainable wetland resource management policies, not only in Yala wetland but also in other such ecosystems both nationally and elsewhere.

1.4 Objectives of the study

1) To map, estimate and characterize spatial temporal land cover/use changes in
Yala wetland

2) To examine the spatiotemporal characteristics of population growth in the study area and identify the linkages with land use land cover changes in Yala wetland

3) To identify and document sustainable measures for utilization of Yala wetland resources.

1.5 Research questions
The study sought to answer the following questions

1. What are the spatial-temporal land cover land use changes that have accrued in Yala wetland between 1990 and 2014?

2. What are the linkages between population growth and wetland land use land cover changes?

3. What are the sustainable measures for utilization of Yala wetland resources so as to reduce environmental and socio-economic impacts?

1.6 Hypotheses
From the above objectives, the following hypotheses were drawn for testing:

HAO1: There are significant spatial and temporal changes in land cover types due to land use changes in the Yala wetland over the study period

HAO2: Spatiotemporal characteristics of population growth in the study
area have direct linkages on land use land cover changes in the Yala wetland

1.7 Scope of the study

The focus of this study was to identify, characterize and examine spatial and temporal biotic cover types to be used as indicators of land use changes in the wetland. The key drivers of the land use changes we presumed to be human population and ecological changes. The overall goal was to provide data and information that will be used in the design of sustainable policy and management interventions for the wetland.

1.8 Operational Definition of Terms

**Remote sensing** the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information to various uses.

**Overall accuracy** the percentage of correctly classified points from the field visited set.

**Resampling** the digital process of changing the sample rate or dimensions of digital imagery by temporally or aerially analysing and sampling the original data.

**Choropleths (maps)** a thematic map in which predefined areal units are shaded or patterned in proportion to the measurement
of the statistical variable being displayed on the map, such as population density or per-capita income.

1.9 Knowledge gaps

The main gap addressed by this study was the linkages between the observed pixel characteristics and the socio-ecological factors that drive the processes of change in order to provide information for future sustainable management of the wetland. Land use is a human activity that directly alters the physical environment. The activities performed by man as he uses the land reflect human goals that are shaped by underlying social driving forces. Proximate sources change the land cover, with further environmental consequences that may ultimately feedback to affect land use (Turner, 1992). This calls for a robust analytical framework that is capable of integrating both realms of the natural and social science research. A useful starting point would be to seek to better describe and understand the nature of driving forces, how they function and interface with the ecosystem, and in particular the effects they exert on the ecosystem in response to environmental pressures, both anthropogenic and non-anthropogenic. This is the overall philosophy of the Pressure-State-Impact-Response (P.S.I.R.) concept and further developed over time to become the Drivers-Pressure-Impact-response (DPSIR) and one of the most widely used frameworks for these sort of studies (OECD, 1994).
1.10 Conceptual Framework

The D-P-S-I-R conceptual framework (Figure 1.1) presupposes that for any given ecosystem on the earth’s surface (defined in the present study as the Yala wetland ecosystem) there will exists a spatial distribution of socio-economic activities and related land uses. The spatial distribution of such anthropogenic activities i.e. Population dynamics reflects the overall demand for a variety of goods and services i.e. changes in land use for food production from within and/or from without the area due to endogenous or exogenous influences.

The consequence of these demands is a build-up of environmental pressure i.e. increased conversion of wetland biotic cover types into agricultural cover types, over-harvesting of papyrus or other wetland products. This is generated through the socio-economic driving forces such as population increases, landlessness, food production, market values of wetland products etc. The driving forces and pressure causes changes in ecosystem’s state i.e. reduced spatial extent of the wetland and reduced macrophyte quantities or quality. Thus, the production activities will result in various types and quantities of residuals, as well as goods and services also measured variously. Such changes in the State of the ecosystem have impacts on the human and non-human receptors resulting in a number of perceived social welfare changes (benefits and costs).
The present study therefore applied this framework of analysis to provide useful insights into the underlying causal relationships between human activities, resultant impacts on the Yala wetland ecosystem and concomitant responses by; Providing relevant information on the various DPSIR elements, clarifying ways in which they are connected and related to each other and examining the effectiveness of the various response mechanism in the study.

Figure 1.1: The DPSIR Concept Source: Modified from OECD, (1994), MEA (2005) and Turner et al., (1998).
1.9 **Significance of the study**

The research will provide up to date maps of the land cover land use maps of the Yala wetland that can be used by the different stakeholders in decision making processes. The study seeks to suggest good sustainable measures for reclamation of the wetland and also for utilization by the residents these can be used ensure coexistence of the wetland and the residents. Lastly, the research will provide literature review for future studies in various fields.
CHAPTER TWO
LITERATURE REVIEW

Wetlands ecosystems exist in the landscape where the water balance ensures an adequate water supply at or near the surface. They are restricted to locations where, on average, precipitation exceeds evaporation loss, or where sustained inflows from surface or subsurface sources alleviate the water deficit (Crafter et al., 1992). These ecosystems include lakes, rivers, rice fields, marshes, fens, peatland and coastal regions to a depth of 6 meters at low tide (Crafter et al., 1992; Dugan, 1993; Mitsch, and Gosselink, 2000; Millennium Ecosystem Assessment Report, 2005). As defined by the (Ramsar convention on Wetlands of 1971, wetlands are “areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water, the depth of which at low tide does not exceed six metres”

This may include ‘riparian and coastal zones adjacent to the wetlands, or islands or bodies of marine water deeper than six metres at low tide laying within the wetland Hollis et al. (2000) such environments. For example, according to bathymetric data generated by Maltby (1993), many parts of the Winam Gulf portion of the Lake Victoria adjunct to the vegetated Nyando wetland study site areas are classified as wetlands since they fall within this depth range.
According to Hollis et al. (2000) and Mitsch et al. (2009), wetlands are dynamic systems; not only connected physically and socially with processes occurring over a much wider territory but they also provide many services that contribute to human well-being and poverty alleviation within such a territory. Maltby, (1993) has referred to wetlands as “a water logged wealth” whose functionality attains a unique and peculiar position in the ecosystems of the world due to their hydrologic conditions and their ecotonal characteristics. Ecotonalism in wetlands implies that they partly share features of both terrestrial and aquatic systems and are remarkably productive ecosystems Mitsch and Gossellink, (2000). This gives them, high agricultural potential and provides opportunities for an all season agricultural activity. These ecotonal characteristics have attracted human activities in these fragile ecosystems making them the new and threatened frontiers of development (Mitsch, and Gossellink, 2000,).

Crafter et al, (1992), defines wetlands as areas of marsh, fen, peatland or water, whether natural or artificial permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters. He describes wetlands as lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin et al, 1979). For regulatory purposes under the Clean
Water Act, the term wetlands means "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetland is a collective term used to describe land where an excess of water (that is water logging) is the dominant factor determining the nature of the soil development, Turner et al, (1997) describes wetlands as an area of land whose soil is saturated with moisture either permanently or seasonally. Such areas may also be covered partially or completely by shallow pools of water.

2.2 Drivers of Land cover Changes in wetlands

2.2.1 Changes in Land use

Land use is further more elaborately defined by Liverman and Cuesta (2008) as the human activity that occurs on the land such as agriculture or grazing and may include additional social characterizations such as subsistence or commercial agriculture. Land cover on the other hand is as the physical and biological cover on the land including vegetation of various types such as papyrus or grassland, water or bare soil and normally indicates the kind of activity to which the specific location on the ecosystem is assigned by human reasoning (Dixon, 2005). Such human reasoning leads to various land use decisions which therefore modify the land characteristics in ways that often introduce new uses (Barbier, 1994). Use cannot be measured directly but is often estimated through the observation and
measurement of indicators of use such as the predominant land cover types on the affected land areas (Barbier, 1994).

Faced with land scarcity, demographic growth, rising poverty, severe economic stresses (Dugan, 1992) and precarious weather patterns in a drying up climate, communities have invaded the wetlands in order to manage them to provide both food and additional income for their livelihoods. This invasion has led to the conversion of large areas of wetlands from their natural state to new uses to meet the needs of the communities. The conversions from one cover type to another are referred to as land use changes. Despite the functional importance of wetlands, some institutions as well as human societies still look at them only in terms of their potential to provide farm land for food, which normally requires alteration of the natural systems of these ecosystems (Barbier et al., 1997). People who live in areas where wetlands play an important role in the sustenance of livelihood support systems are generally affected by the effects of the changes (Dixon, 2005). Some groups of people, particularly those living near wetlands, are highly dependent on the services that wetlands and their livelihoods are directly harmed by their degradation (Hollis et al., 2000).

In many of these circumstances, wetland benefits are regarded as a type of public good since they display characteristics of non-excludability and non-rivalry in consumption (Hodge and McNally, 2000). In their use of these ecosystems, communities have for centuries generally treated wetlands as common property
resources. Each community has had its own tradition and practices in utilization and management of such resources based on their indigenous knowledge. However, as noted by Makalle et al. (2008) an asset that is everyone's property as is the case in most wetland ecosystems is in fact no one's property and they are often mismanaged or overused.

Prediction of the nature of impact such conversions could trigger or cause in a watershed is precarious, location specific and influenced by a series of compounding factors. Some of the factors are anthropogenic in nature. Anthropogenicity is often a function of the cultural inclinations of the change agents Owino and Ryan (2007). This is particularly so in tropical environments. Makalle et al. (2008) found that such cultural inclinations lead to unsustainable practices that drive processes of the degradation of not only wetlands but also other ecosystems. Their work, for instance reveal conspicuous changes in community livelihoods as a result of expansion of cultivation, overgrazing on the river banks, increased use of wetlands areas, the disappearance and extreme fragmentation of forest, bush land and appearance and the diminishing of settlements. Owino and Ryan (2007) for instance attribute phenomenal losses of wetland habitats in the study area to increased demand for agricultural land and papyrus products.

Land use therefore stands out as one of the most import critical and direct driver
of wetland loss (the Millennium Ecosystem Assessment Report, 2005). According to Geist and Lambin, (2002) proximate causes, are human activities or immediate actions at the local level, such as agricultural expansion, that originate from intended land use and directly impact on cover types. Besides the economic motives for land-use change.

In an attempt to provide evidence of the anthropogenic pressures being exerted on wetlands, Dixon and Wood (2003) examined the relationships between wetland characteristics that may be related to land use practices. Locations adjacent to the wetland environments and plant species richness and community composition. They concluded that differences in the land-use-diversity relationship among different plant functional groups suggest that adjacent land use affects wetland plant communities. They suggested that current management practices are inadequate and that regulation of adjacent land use being a major driver of the changes occurring in the wetlands. The changes are a critical component of wetland conservation and management. In this effort, the institutions, perceptions and attitudes of riparian communities as they exploit the wetlands are critical and need adequate attention.

Timoney (2002) suggested that the factors that contribute to the lack of socio-ecological understanding to generate the desired information to design response measures include problems of data quality, quantity, and scale, ecological
complexity and failure to consult or analyse older/historical datasets, especially spatial, as a basis for planning the future of these important ecosystems. His work further blames over-reliance on gray literature, too few wetland ecologists, and too little interdisciplinary thinking. A further obstacle identified (Turner et al., 1998) is that such areas occur in the remote areas where rural problems have continued to be lowly prioritized by central governments in many developing countries like Kenya, Uganda, Tanzania, Gabon and many other West African states.

Liverman and Cuesta (2008) noted that most studies have failed to link the social and natural sciences through the study of land-use and land-cover changes. The applicability of tools such as GIS and remote sensing capable of accessing the difficult terrains that are wetland environments with socioeconomic data as they have impacts on resource health, local case studies with larger scale modelling efforts, and scientific research with the needs of stakeholders. Consequently, adequate progress in understanding the human causes of land-cover change is frustrated by temporal, spatial and conceptual inconsistencies between social, satellite and physical science data sets.

2.3 Human Population Growth
A close association has been inferred between population growth and land use changes not only in the terrestrial landscapes but also in ecotonal landscapes such
as wetlands. It was found that population growth and land use are interdependent variables where population growth is a function of land use for the simple reason that nobody wants to live on barren land Mavuti (1992) The increasing world population results rising demands on the earth’s resources Liverman and Cuesta (2008). At the same time human societies are becoming more organized not just to ensure that people have sufficient land and natural resources for basic needs, but to support the multifarious activities of the increasingly complex social and economic behaviour patterns Maitima et al (2010). It is also emerging that the primary cause of land use conversions has been the need to meet the demands of the increasing population not only in the study area but also in entire Lake Victoria basin. This includes need to provide increased quantities of raw materials to support local agro-based industries which also serve the interests of the growing populations Owino and Ryan (2007).

According to Owino and Ryan (2007) many of the problems affecting the wetlands in the study area are influenced directly or indirectly by demographic dynamics such as population size, population growth rates, population densities, and migration of peoples. However, there exist such mediating factors as income levels, consumption patterns, technological structure, and economic and political institutions. Even though, these intervening parameters often make it difficult to establish, with scientific precision. A clear correlation between population pressures and environmental degradation the study also notes that it is also hard to
disagree with the conclusion of a recent study that “the least likely theory is that there are no relationships at all.

Future problems for vulnerable habitats such as wetlands are predicted by current United Nations population projections predict that the population of developing countries will raise to about eight billion by 2025 and nine billion by 2050. The UNEP report, (2004) indicate that population growth will be much faster in Africa. The increase in population will requires massive agricultural expansion and development to feed this added population. This will have environmental implication on landscapes that is ecologically delicate such as drylands and will be targeted for the expansion. Dobiesz, et al., (2010) carried a study to determine metrics for use in measuring ecosystem status found that transitioning systems (such as wetlands which have ecotonal characteristics).

Present indications in the study area are that these pressures will continue to intensify in the future in direct proportion with the population increases. The grim facts are that according to (Oucho 1993), the demographic profile of the region is characterized by a rapidly expanding human population. For example, in 1962 and 1969, the population of Nyanza Province alone stood at 1 million and 2.1 million, respectively. In 1993 and 2009, the population was estimated at 4.5 million (KNBS, 2010) respectively indicating a growth rate well above the average national rate of 3.4%. This population needs clothing, food and shelter.
that have to be met from the natural resource base which includes the wetlands.

Keya and Michieka,(1993)

2.3.1 Population change dynamics
Size, compactness and frequent political changes of boundaries of these units as well as the variability of the distribution mapped Owino and Ryan (2007) are important factors in determining the accuracy of aggregate values calculated for the units. Analysis indicates that all the three variables exert a significant influence on accuracy of aggregate values with surface variation accounting for the greatest portion of the variation in accuracy.

Choropleths mapping is a common cartographic technique used by geographers and other researchers dealing with spatial information to visualize geo-spatial enumeration data in such units. A Choropleths map (sometimes referred to as an area-value map) reveals patterns within data by showing the distribution of the chosen phenomenon within the selected area. Generally, reading relationships to discover a similarity or difference among the map patterns in a time series environment has been possible only when individual Choropleths (maps) were read separately and then compared with each other. Experiments have proven that in many circumstances, the human vision is misleading in this process

Turner et al. (1998) however successfully, used bivariate Choropleths method by covering each such aerial unit by a tone (or pattern) representing a combination of
the values of two variables to portray two separate phenomena simultaneously
and infer the spatial relationships between the variables. It should be noted that
maps can only show the coincidence of the distributions; to state the casual
relationship between variables, the phenomena must be interpreted in a broader
context. Use of GIS and human context analysis tools to understand the human
population dynamics such as human population growth, density and migration in
and around protected areas such as wetlands. These methods rely heavily on
 rasterized Choropleths for overlay analysis.

2.4 Threats to wetlands existence
Increasing human population, coupled with the growing need for increased food
production to meet the high demand, have put tremendous pressure on wetlands
around the world (O’Connell, 2013). At the global level, human activities pose the
greatest threat to the well-being of wetlands, resulting in either their loss or
degradation (Bjerstedt, 2011). Wetland loss is defined as “the loss of wetland area
due to conversion of wetlands to non-wetland areas as a result of human activity”.
Wetland degradation is “the impairment of wetland functions as a result of human
activities (Moser et al, 1996). Other threats to wetlands are natural activities like
mass wasting, sea level rise, drought, hurricanes and overgrazing by wildlife.
However, all these natural processes and activities are closely linked to man’s
activities on the planet. These threats have induced changes that have eroded the
ecological and socioeconomic values and services derived from wetlands.
Overall, the underlying threat remains the lack of recognition of the importance of
wetlands and the roles they play in national economies and indigenous peoples’ livelihoods (Oucho, 1993)

According to Ramsar Convention Secretariat, (2006) more than 220 million acres of wetlands are thought to have existed in the lower 48 states in the 1600s in the world. Since then extensive losses have occurred, and more than half of our original wetlands have been drained and converted to other uses. The mid-1950s to the mid-1970s were a time of major national wetland loss. Since then the rate of loss has slowed.

The concept of degradation refers to a change in state from a complex to a less complex structure. Wetland degradation is a process which has been widely addressed in Ramsar publications. Hollis, (1993) consider this process as the impairment of wetland functions as a result of human activity. This process is hardly isolated from that of wetland loss. When the degree of impairment goes above certain limits, it becomes difficult to reverse; this means the wetland has been degraded to a point of loss.

Wetland degradation culminates in a loss in wetland area. Wetland degradation is also often considered in terms of the change in quantity of wetland resources around a baseline. This is manifested by the loss in biodiversity, change in wetland water quality/ flow patterns, scarcity of wetland resources, destruction of
ecosystems, loss in aesthetic, cultural and spiritual values of wetlands and the appearance of new species (Schuijt, 2002). In this research, wetland degradation will be considered in terms of transformation in areas once occupied by wetlands which have been ceded to other uses (transformed surfaces), lost wetland areas, the change in the biodiversity, a change in water flow patterns and the change in turbidity and water quality in and out of the wetland areas (Schuijt, 2002).

As earlier mentioned, it is seen that wetlands are ecosystems that are currently over exploited to a point of degradation. To evaluate degradation of wetlands, other concepts need to be understood, the main ones being the concepts of Wetland values and wetland functions. According to the World Bank Group (2004) wetland values refer to all wetland products that can be exploited towards satisfying human needs and can therefore be evaluated fiscally. Products that can be evaluated/quantified here include fish, trees, birds, edible amphibians, worms, recreation and landscape, input into food chains, wetland vegetation, foods crops cultivated, hydroelectric power generated etc (World Bank Group 2004).

On the other hand, a wetland function refers to an aspect of a wetland that supports human activities or protects natural systems or natural processes, (for example flood control, toxic pollutants, wildlife resources, micro climate stabilization, fisheries, water supply) without being used directly. Approximately 100 million wetland acres remain in the 48 contiguous states, but they continue to
be lost at a rate of about 60,000 acres annually Ramsar Convention Secretariat, (2006).

Draining wetlands for agricultural purposes are significant, but declining, while development pressure is emerging as the largest cause of wetland loss. Unfortunately, many remaining wetlands are in poor condition and many created wetlands fail to replace the diverse plant and animal communities of those destroyed. When a wetland functions properly, it provides water quality protection, fish and wildlife habitat, natural floodwater storage, and reduction in the erosive potential of surface water. A degraded wetland is less able to effectively perform these functions. For this reason, wetland degradation is as big a problem as outright wetland loss, though often more difficult to identify and quantify (Timoney, 2002).
CHAPTER THREE
MATERIALS AND METHODS

3.1 Description of the study area
Yala swamp is the largest freshwater inland wetland in Kenya, covering an area of 17,500 ha. It is located in the Yala delta on the northeast shore of the Lake Victoria basin coordinates extend from latitude 0º to 0º 45 North and longitude 33º55’ to 34º25. The wetlands are (Figure 3.1) at an altitude of 1,140m and 1,150m above sea level (Kenya Wetlands Forum 2006). The swamp traverses Siaya and Busia counties but the larger part of it is in Siaya County This study concentrated in Bondo, Budalangi and Boro divisions are the major administrative divisions that surround the Yala swamp wetland

The swamp was formed through the back flow of water from Lake Victoria and the flooding of rivers Yala and Nzoia, River Yala is the main source that feeds the swamp. Within the swamp there are three lakes, namely, Lake Kanyaboli (1000 ha), Lake Sare (500 ha) and Lake Nyamboyo (1 ha) Birdlife International, (2012). The dominant vegetation is papyrus. (Cyperus papyrus) mainly found in the deeper areas, while Phragmites mauritianus is in shallower areas and swamp grasses around the periphery. It is home to threatened species such as the Sitatunga antelope (Tragelaphus spekei.) In addition, the swamp serves as a natural filter for biocides and other pollutants from the surrounding catchment. It
also filters silt from the river water through sedimentation before it flows into the lake (Kinaro, 2008; Bird Life International, 2008)

3.1.1 Climate

The climate of the area is mainly tropical humid characterized by day temperatures varying between 16°C to 28°C in the lower semi-arid areas on annual basis. The mean annual night temperatures vary between 4°C in the highland areas to 16°C in the semi-arid areas. Mean annual rainfall varies from a maximum of 1100 to 2700 mm and a minimum of 600 to 1100 mm (Raburu, 2004). The area experiences four seasons in a year as a result of the inter-tropical convergence zone (ITCZ). There are two rainy seasons and two dry seasons, namely, short rains (October to December) and the long rains (March to May). The dry seasons occur in the months of January to February and June to September. However the local relief and influences of the Lake Victoria modify the regular weather pattern Kenya Meteorological Department (2008)

3.1.2 Soils

Yala swamp and is characterized by solids having moderate to low fertile soils (mainly ferrasols with underlying plinthite ‘murram’) with poor water retention, which can support crop production if provided with nutrient support (i.e. fertiliser) (Siaya District Development Plan 2002–2008)
3.1.3 Socio economic activities
Crop production has, for most households, overtaken fishing and livestock farming as the key economic activity. The present land-tenure system limits livestock movement and grazing space. Income from fishing around the lake has shrunk because of increased water pollution, over fishing and poor fishing techniques, leading to the fish depletion from both lake Victoria and Lake Kanyaboli (Owino and Ryan 2007). One hundred twenty thousand farm families, (80% of the district’s population,) engage in crop and livestock production. In addition, 60% of the household income comes from agriculture and rural self-employment activities (Siaya District Development Plan 2002–2008). Continuous cultivation, monoculture and poor land management have increased pressure on land

Figure 3. 1: The study area map showing the Yala swamp and its environs.
3.2 Research Design
This study relied on both primary and secondary data. Secondary data was be obtained by carrying out literature review on studies so far done on the subject matter in the study area or elsewhere. Population data of the study area was obtained from the Kenya National Bureau of Statistics since the 1989 which had been set as the base year for the study. Others such as journal articles, reports, theses and field measurements of the changes in cover types to indicate changes in the uses of the wetland ecosystem were estimated by use of satellite images complimented by aerial photographs. Satellite images data was obtained from institutions Regional Centre for Mapping of Resources for Development (RCMRD) Nairobi.

LANDASAT-TM images for the period 1990, 2000, 2010 and 2014 were analysed. This were considered appropriate for the study due there relatively good resolution were further resampled to a higher resolution to cost effectively cover the needs of the study. 2014 satellite image was also used mainly to show the current status of the wetland

3.3 Observations
The researcher used observation as a tool in collecting data that was used to verify whether the information given by the respondents are in any way related to the observable features in the sample unit.
3.4 Sampling Frame, Sample Size and Design

The sampling frame for the study was estimated at 201869 households based on the 2009 household census, Kenya (KNBS, 2010) only an approximately 44412 of this population bearing the most effect as they live closer to the wetland and are within the set boundary of 2 kilometres created around the Yala wetland.

Mugenda and Mugenda Fishers, (1999) fishers formula was used to determine the sample size for this study. A sample size of 243 households was used in this study as given in the equation below.

\[ n = \frac{(Z^2 pqD)}{d^2} \]

Where by
\[ n = \text{the desired sample size}, \]
\[ z = \text{the standard normal deviation at the desired confidence level which is 95\% therefore 1.96}, \]
\[ p = \text{the proportion in the target population estimated to be affected by the wetland i.e. 22\%} \]
\[ q = 1-p, 1-0.22 =0.78 \]
\[ d = \text{the level of statistical significance set at 0.05} \]

\[ n = \frac{1.96^2 \times 0.22 \times 0.78}{0.05^2} = 243.14 = 243 \text{ households} \]
Cluster sampling was first used to group the respondents; in this case sub locations were seen as appropriate clusters. Random sampling was then used to select 242 households to be interviewed within the study area. In each sub location the respondents were selected as given in Table 3.1. This was aimed at giving each sub location an equal representation in the study.

Table 3.1: Number of respondents interviewed per Sub location in Yala swamp and its environs

<table>
<thead>
<tr>
<th>Sublocation</th>
<th>No. Of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Alego</td>
<td>22</td>
</tr>
<tr>
<td>West Yimbo</td>
<td>22</td>
</tr>
<tr>
<td>West Bunyala</td>
<td>22</td>
</tr>
<tr>
<td>West Alego</td>
<td>22</td>
</tr>
<tr>
<td>Usonga</td>
<td>22</td>
</tr>
<tr>
<td>South Bunyala</td>
<td>22</td>
</tr>
<tr>
<td>South Alego</td>
<td>22</td>
</tr>
<tr>
<td>East Yimbo</td>
<td>22</td>
</tr>
<tr>
<td>East Bunyala</td>
<td>22</td>
</tr>
<tr>
<td>Central Yimbo</td>
<td>22</td>
</tr>
<tr>
<td>East Alego</td>
<td>22</td>
</tr>
</tbody>
</table>

The interview was aimed for the head of the household, however, there are instances when it was impossible to miss the targeted respondent the next person
to the head of the household but in instances where both were not available a call back method was applied

3.5 Questionnaire Administration

The questionnaire (Appendix 1) was administered during the survey in a language the respondent was comfortable with. This was done to ensure direct contact between the researcher and the respondent, a factor which facilitates elaboration of aspects that may not have been easily understood by the respondent. The data was analyzed by the SPSS software and was presented in form of tables and charts. 242 respondents were interviewed with 50 being female and 192 male

3.6 Photographic documentation

The researcher also used horizontal digital photography to record observable features that helped in explaining the various issues addressed by the objectives of the study. Data collected using this method is often accurate and reliable as it reflected the actual situation on the ground. The use of photographs enhanced the perception of results from other data collection procedures to show, for instance, the vegetation destruction going on in the wetland, the form and type of land use activities, the extent of recession of the shoreline. Data collected was to pictorially explain the results.

3.7 Data reliability

Population data of the study area was obtained from the Kenya National Bureau of statistics which is the custodian of government data hence the data obtained
from the institution is reliable for use in the research. LANDASAT-TM images in
were considered appropriate for the study due there relatively good resolution of
30 metres which were further be resampled to a higher resolution to cost
effectively cover the needs of the study. The LANDSAT satellite started
delivering good quality images in the mid-1980s hence the images for the study
period were all attained

3.8 GIS and Remote Sensing in change detection
Land use changes were determined through the combined use of both remote
sensing and GIS techniques. The images obtained from institutions in Nairobi the
Regional Centre for Mapping of Resources for Development (RCMRD); Landsat
ETM images with a 30m Resolution were used. Satellite data remains the most
current at affordable cost covering wide area and perhaps the most consistent and
reliable in change detection and trend analysis in a way important for
environmental analysis, the return period for LANDSAT is 16 days.
LANDSAT ETM imagery as a primary data source was used to successfully
determine and map the landscape characteristics particularly plant communities of
Yala swamp. The study utilized, ARC GIS 10, and ERDAS 9.3 in combination
with ENVI 4.7 or IDRISI. Landsat-ETM images acquired were already corrected.
Since each image consists of about six bands. Resampling of the images was the
undertaken this was done in ERDAS using the "Layer Stack" module. Layer
stacking enables band combination thus enabling the image combination in true
color combination (bands 3, 2, 1) or false color composition (4, 3, and 2).
<table>
<thead>
<tr>
<th>Year</th>
<th>Date collected</th>
<th>Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>March 08 1990</td>
<td>Thematic Mapper</td>
</tr>
<tr>
<td>2000</td>
<td>March 01 2000</td>
<td>Thematic Mapper</td>
</tr>
<tr>
<td>2010</td>
<td>Jan 17 2000</td>
<td>Enhanced Thematic Mapper</td>
</tr>
<tr>
<td>2014</td>
<td>Feb 23 2014</td>
<td>Enhanced Thematic Mapper</td>
</tr>
</tbody>
</table>

### 3.9 Clipping

The images were then clipped using the subset module as defined above so as to attain only the study area to be classified, this was done in ARC GIS 10 with the aid of a shape file of the study area, this was done in the data management module-raster processing – clip module in ARC GIS or the subset module in ERDAS 9.3. The shape file used in sub setting the image was obtained from the boundaries of the locations surrounding the wetland. After sub setting the following images in appendix 6 to appendix 9 were obtained.

### 3.10 Image classification

#### 3.10.1 Unsupervised classification

Image classification was then undertaken, unsupervised classification was undertaken for the clipped images using ERDAS 9.3 software to generate classes that are found in area. This is a computer generated and gives a general view of the number of classes that are within the study area. Using the classes obtained and the prior knowledge of the area, tentative classes of ten land uses were assigned to the auto generated classes.
3.10.2 Supervised classification
ERDAS 9.3 maximum likelihood module method was adopted to undertake supervised classification. This method assumed that the training area digital numbers are normally distributed. The probability of a pixel value occurring in each class would then be computed, therefore assigning the pixels to the class with the highest probability (likelihood of being a member). This was repeated for all the images and the results were presented as figures. This process was also aided by a Google Earth image for the area, which is considered real time and ensured that the classified class is a true representation with the situation on the ground.

3.10.2.1 Levels of significance
In testing the hypothesis; Levels of significance of the changes that have occurred within the wetland will be calculated by T-test formula in SPSS. The confidence levels were set at 95% with a significance level of 0.05. This was done for year 1990 and 2000 land covers and the population percentage population change and land use change derived using the supervised classification method. The area in metres square will be used as the arrays.

3.10.3 Change detection
Change detection analysis entails finding the type, extent and location of changes in land-use (Yeh et al., 1996). Various algorithms are available (Jensen, 1996; ERDAS, 1999). The following procedures were used to analyse and detect changes that the study sought to determine. Comparisons in the classified images were undertaken; this involved the determination of the level of disagreements
spatio-temporal changes between images considered for this study i.e. 1990, 1995, 2000 and 2010. This was done using the IDRISI CROSSTAB module, since Erdas does not have the possibility to provide the expected format; In this method, the independently classified images were compared and the results presented on as a map.

3.11 Accuracy Assessment and Ground Truthing
The accuracy of area estimates derived from these maps is known to be related to the accuracy of the map Lillesand, et al (2004). It was therefore important to determine the degree of error in the end products at the end of the above procedures to authenticate the results for planning and management decisions. The errors could occur due to incorrect labelling of pixels (Mather, 1987), poor geometric registration and, calibration or normalization between multi-temporal images, the quality of ground truth data, and the complexity of landscape and environments of the study area among others Lu et al. (2004). The study used one of the most commonly used method of assessing the accuracy of a classification known as the error matrix calculation to compare the agreement between classes predicted through image processing procedures to those observed independently of the classification.

Accuracy assessment elements included overall accuracy, producer’s accuracy, user’s accuracy and Kappa coefficient Lu et al. (2004) The CROSSTAB routines in IDRISI or ERDAS were used to generate the desired measures of association.
among the map overlays such as the kappa index of Agreement. The kappa was evaluated as an index for the agreement between the images, thus giving an indication of the overall amount of change that will have taken place. The index was evaluated according to Jansen (2004) on a per-category basis. In this case it was used to express the degree to which a particular category agrees between two dates. The per-category Kappa data was tabulated and used to quickly gain an appreciation of which categories are the major ones affected by the changes in land cover, and the nature of that change within the IDRISI/ERDAS Imagine 9.3, environment. This involved the gathering of field reference data and comparing mapped conditions with known conditions on the ground. Accuracy assessment locations were randomly generated in a multi-stage geographically stratified random format using the sampling tools in ERDAS Imagine 9.3 to define a minimum of 75 points for both wetland increase and wetland decrease classes. Each of the sample sites were identified as a field plot of approximately 2x2 pixels in size as modified from the recommendations of Young-Haines, and Green (1992) and located using the Garmin 12 GPS.

These considerations were informed by the number of points chosen to assess accuracy in literature which range from 50 to 200 points per site (Observations were collected independently through visual interpretation of imagery by visiting selected sample sites according to Young- Haines, and Green, (1992). The overall classification accuracy was calculated as the average of the individual class
accuracies expressed in percentage terms in the GIS environment.

Ground truthing excursions were carried out to verify and match the various spectral characteristics forming the photomorphic regions with ground situations. After ground trothing, boundary adjustments were done and new overlays prepared for each time step in the time series to be introduced into the change vector analysis process.
CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 Analysis, characterization and Image Interpretation Results
Four satellite images for four different years were used to achieve this objective that is the 1990, 2000, 2010, and 2014 images giving it a ten year span except for the final year 2014 which was used to show the most current state the wetland. The ERDAS software which is widely known for image interpretation was used in the analysis of the satellite images.

4.1.1 Unsupervised classification
Unsupervised classification was undertaken and ten classes deduced from the results, these classes would later be used in defining the final classes in supervised classification. The classes identified at this point of classification were;

1. Lake
2. Waters with shallow vegetation
3. Open waters in the swamp
4. Turbid water surface
5. Swamp
6. Irrigated farm
7. Rice farms with turbid water surface
8. Open grassland with exposed bare ground
9. Small subsistence agriculture
10. Exposed bare ground
The images are given in figures 4.1 to 4.4

Figure 4.1: Unsupervised classification image results for the year 1990 in Yala wetland

Figure 4.2: Unsupervised classification image results for the year 2010 in Yala wetland
Figure 4.3: Unsupervised classification image results for the year 2000 in Yala wetland.

Figure 4.4: Unsupervised classification image results for the year 2014 in Yala wetland.
4.1.2 Supervised classification
Supervised land classification using maximum likelihood in ERDAS 9.3 for the clipped images in appendix 4.6 to appendix 4.9 images was undertaken with the aid of the unsupervised images. The 1990 and 2000 images were classified into six classes as compared to the 2010 and 2014 image which had seven classes. This was due to the fact the large scale rice farming had not been introduced in the area up to the year 2005, leading to the omission of the Rice paddies class in the classification of the images of the year 1990 and 2000. Figures 4.5 to 4.8 below gives the land use land cover classification results per year and the identified classes were as follows

1. Swamp/wetland
2. Lakes
3. Shallow Water
4. Settled Areas with cultivated land
5. Cleared Areas for Cultivation
6. Grassland/Shrub
7. Rice paddy
Figure 4.5: Supervised Classification land use land cover image results for the year 1990 in Yala wetland

Figure 4.6: Supervised Classification land use land cover image results for the year 2000 in Yala wetland
Figure 4.7: Supervised Classification land use land cover image results for the year 2010 in Yala wetland.

Figure 4.8: Supervised Classification land use land cover image results for the year 2014 in Yala wetland.
4.1.3 Land use Land Cover Changes

Analysis of the images of 1990, 2000, 2010 and 2014 relieved that there were major changes that Yala wetland has undergone through the 25-year period (Table 4.1).

Table 4.1: Land use Land Cover Changes 1990-2014 in Yala wetland and its environs

<table>
<thead>
<tr>
<th>Land use</th>
<th>1990</th>
<th>2000</th>
<th>2010</th>
<th>2014</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swamp/wetland</td>
<td>188231</td>
<td>167251</td>
<td>142018</td>
<td>125787</td>
<td>33.2</td>
</tr>
<tr>
<td>Lake</td>
<td>119788</td>
<td>120091</td>
<td>113281</td>
<td>110875</td>
<td>7.5</td>
</tr>
<tr>
<td>Shallow Water</td>
<td>14342</td>
<td>18291</td>
<td>17173</td>
<td>13311</td>
<td>7.1</td>
</tr>
<tr>
<td>Settled Areas with cultivated land</td>
<td>44943</td>
<td>147684</td>
<td>180276</td>
<td>260401</td>
<td>50</td>
</tr>
<tr>
<td>Cleared Areas for Cultivation</td>
<td>14241</td>
<td>23661</td>
<td>34662</td>
<td>41159</td>
<td></td>
</tr>
<tr>
<td>Grassland/Shrub</td>
<td>252386</td>
<td>104174</td>
<td>94397</td>
<td>42000</td>
<td>83</td>
</tr>
<tr>
<td>Rice Paddy</td>
<td></td>
<td></td>
<td>4124</td>
<td>5238</td>
<td>21.2</td>
</tr>
</tbody>
</table>

There was a general reduction in the area occupied by the swamp as shown in Figures 4.9 to 4.12. This was achieved by grouping the wetland and representing it as a lone entity as shown.
Figure 4.9: Area occupied by the swamp in the year 1990 in Yala wetland

Figure 4.10: Area occupied by the swamp in the year 2000 in Yala wetland
Figure 4.11: Area occupied by the swamp in the year 2010 in Yala wetland

Figure 4.12: Area occupied by the swamp in the year 2014 in Yala wetland
The figure 4.13 gives the changes that have taken place within the wetland areas between 1990 and 2014. The wetland size has drastically reduced by 33.17% from the figures obtained from Land use land cover analysis in ERDAS and also tabulated in table 4.1

![Wetland in 1990-2014](image)

Figure 4 13: Area occupied by the Wetland from 1990 to 2014 in Yala wetland

**4.1.4 Image analysis Changes Results**

There was a 7.5% decrease in the area occupied by the lakes from 1990 through to 2014. Shallow waters had a slight reduction of 7.1% in the area; this could be attributed to siltation as observed in the area waters. There was an increase in the area occupied by settled areas with cultivated farms by 50% due to increase in population, cleared areas for cultivation had an increase of 65% between the year
1990 and 2014. This was due to the fact that the study area has had a steady increase in the population as from 1990. Grassland /shrubs also decreased by 83% elucidating that most of these areas have been cleared for other land uses. Commercial rice farming (rice paddies) which introduced large scale rice farming in the area as from 2005 has been also on an upward trend increasing the area occupied by these activities by 21.2% from the year 2010 to the year 2014. The figure 4.15 gives these land use land cover changes explaining further the changes in land use and land cover activities in the area. The numbers 1-7 represents the classes’ identified during the supervised classification process;

1. Swamp/ wetland
2. Lake
3. Shallow Water
4. Settled Areas with cultivated land
5. Cleared Areas for Cultivation
6. Grassland /Shrub
7. Rice paddy

The area occupied by grassland / shrubs which reduced by 83% can be attributed to the continuous increase in the areas of settled area which increased by 50% and cultivated areas which was on an upward trend increasing by 65% through the years 1990 to 2014. Cultivated areas also occupied areas that were formally occupied by shallow waters and this was evident as there was an increase in siltation observed in the waters. In the Figure 4.14 numbers 1-7 represents the
land use land cover classes in the study area. Value 8 represents the unchanged areas over the study period.

![1990_2014 Crosstab Image](image)

Figure 4.14: Change detection results 1990_2014 images in Yala wetland

### 4.1.4.1 Testing of Hypothesis HAO1

The hypothesis was tested using the Ttest function in SPSS. Using the area occupied by the different land uses in 1990 and 2014 as the variables (Table 4.1)

After testing of HAO1 of the study a P-value of 0.9223 was obtained thus leading to the conclusion that there are significant spatial and temporal changes in land cover types due to land use changes in the Yala wetland over the study period, this hypothesis was accepted.
4.1.5 Accuracy assessment results

Accuracy assessment was performed for all supervised classified areas. Historical aerial photographs for the study area were useful for this exercise as well as points collected on the ground for truthing were taken. Maps, field survey and interviews with the indigenous people facilitated the exercise. Yang & Lo, (2002) commented that an assessment of a LANDSAT TM-based land use and cover map should be sufficient to shed light on the overall accuracy of the land use/cover mapping where not enough spatial coverage data is available, this was adopted for this study.

The overall accuracies were high as observed they ranged from 72% to over 97% with a Kappa index of 0.72 to 0.87 (Table 4.2). User accuracies were higher, which means many LULC were labeled correctly. All classified images which were used for change labelling had accuracies above 72% and Kappa indices above 0.72. Since the acceptable accuracy level had been set at 70%, the accuracy assessment test for this research was at 84.16%, therefore the results were accepted.
# Table 4.2: Accuracy assessment Results

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Reference Totals</th>
<th>Classified Totals</th>
<th>Number Correct</th>
<th>Producers Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unclassified</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>---</td>
</tr>
<tr>
<td>Lake Water / Shallow waters</td>
<td>20.48</td>
<td>18</td>
<td>16</td>
<td>88.88%</td>
</tr>
<tr>
<td>Rice paddies</td>
<td>21.92</td>
<td>22</td>
<td>16</td>
<td>72.77%</td>
</tr>
<tr>
<td>Wetland/ Swamp</td>
<td>23.52</td>
<td>39</td>
<td>38</td>
<td>97.4%</td>
</tr>
<tr>
<td>Open grassland, with small shrubs</td>
<td>24.24</td>
<td>22</td>
<td>18</td>
<td>79.72%</td>
</tr>
<tr>
<td>Settled Area for cultivation / Cleared Areas</td>
<td>49.84</td>
<td>39</td>
<td>32</td>
<td>82.07%</td>
</tr>
<tr>
<td>Wetlands / Swamp</td>
<td>140</td>
<td>140</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td><strong>Overall Classification Accuracy =</strong></td>
<td></td>
<td></td>
<td></td>
<td>84.16%</td>
</tr>
</tbody>
</table>

Kappa ($\kappa^*$) Statistics

Overall Kappa Statistics = 0.8591

Conditional Kappa for each Category.

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unclassified</td>
<td>0</td>
</tr>
<tr>
<td>Lakes/shallow waters</td>
<td>0.7235</td>
</tr>
<tr>
<td>Settled areas for cultivation / cleared areas</td>
<td>0.8189</td>
</tr>
<tr>
<td>Rice, Sugarcane Farmlands</td>
<td>0.8662</td>
</tr>
<tr>
<td>Open Grassland/Shrubs</td>
<td>0.7409</td>
</tr>
<tr>
<td>Wetlands / Swamp</td>
<td>0.8715</td>
</tr>
</tbody>
</table>
4.2 Population change dynamics and Land Use Land Cover Change

Based on the 1989, 1999 and 2009 household study in Kenya, the estimated population for the areas within the study areas were as represented in the Table 4.3. The population of the following locations was used in defining the study area population due to the fact that they lie within the boundaries of the study area and within five kilometers from the boundary of the wetland West Yimbo, West Bunyala, South Bunyala, Usonga, West Alego, Central Alego, East Yimbo, South Alego and East Alego.

Table 4.3: Number of households in study Area from 1989-2009 (KNBS, 1989, 1999, 2009)

<table>
<thead>
<tr>
<th>Population</th>
<th>1989</th>
<th>%Change</th>
<th>1999</th>
<th>%change</th>
<th>2009</th>
<th>%change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Alego</td>
<td>27802</td>
<td>47</td>
<td>40897</td>
<td>76</td>
<td>51564</td>
<td>52</td>
</tr>
<tr>
<td>West Yimbo</td>
<td>16072</td>
<td>70</td>
<td>27456</td>
<td>27</td>
<td>35128</td>
<td>55</td>
</tr>
<tr>
<td>West Bunyala</td>
<td>13387</td>
<td>52</td>
<td>20375</td>
<td>54</td>
<td>31421</td>
<td>66</td>
</tr>
<tr>
<td>West Alego</td>
<td>28517</td>
<td>50</td>
<td>42808</td>
<td>17</td>
<td>50356</td>
<td>61</td>
</tr>
<tr>
<td>Usonga</td>
<td>11059</td>
<td>79</td>
<td>19814</td>
<td>65</td>
<td>30238</td>
<td>78</td>
</tr>
<tr>
<td>South Bunyala</td>
<td>16858</td>
<td>60</td>
<td>26853</td>
<td>76</td>
<td>35126</td>
<td>49</td>
</tr>
<tr>
<td>South Alego</td>
<td>22034</td>
<td>20</td>
<td>25582</td>
<td>79</td>
<td>32156</td>
<td>35</td>
</tr>
<tr>
<td>East Yimbo</td>
<td>11567</td>
<td>65</td>
<td>19432</td>
<td>77</td>
<td>25189</td>
<td>68</td>
</tr>
<tr>
<td>East Bunyala</td>
<td>6301</td>
<td>38</td>
<td>14901</td>
<td>16</td>
<td>20354</td>
<td>95</td>
</tr>
<tr>
<td>East Alego</td>
<td>43305</td>
<td>46</td>
<td>63675</td>
<td>90</td>
<td>70125</td>
<td>43</td>
</tr>
<tr>
<td>Central Yimbo</td>
<td>6964</td>
<td>86</td>
<td>12176</td>
<td>75</td>
<td>16234</td>
<td>53</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>205855</strong></td>
<td></td>
<td><strong>313969</strong></td>
<td></td>
<td><strong>397891</strong></td>
<td>65</td>
</tr>
</tbody>
</table>

54
The human population in the study area has been on a continuous steady increase of 83% since the 1989. This increase has direct effects on the wetland and the land use land cover changes. These can be supported from the interpretation of the satellite images in Figures 4.14 where there was a continuous increase in settled areas at 50% with cultivated farms, open grasslands with small shrubs and cleared areas for cultivation as compared to wetland/swamp class was reducing in size over the 24 year period.

Yala wetland is being faced with majority of these problems, there has also been rapid development in the area which has led to growth of small trading centers, construction of infrastructure and migrations all of which need a great deal of land to be fully developed. This has put pressure on the wetland as these factors and their combination continue to enhance degradation of the wetland ecosystems.

Most households at 46% in the study have 6-8 members (Figure 4.15).

![Figure 4.15: Number of individuals per household in the Yala wetland](image-url)
The population in the area has low education levels which are an indication of high levels of poverty. According to the results of the questionnaire administered most of the residents interviewed in the area have an upper primary education at 70% with the least having university studies 4% and also do not reside in the area (Figure 4.16).

Figure 4.16: Levels of education levels among the respondents in Yala wetland and the environs

Most of the activities the respondents engage in are partly dependent on the wetland resources. Activities such as mat making at 29% and rope making at 21% depend mostly on papyrus reeds vegetation (Figure 4.17).
4.2.2 Land ownership
Some of the local community still believed they still own land in the swamp according to the field survey where most of the area residents own the land through inheritance or were managing family land; 40% and 42% respectively. 13% have bought the land and at least 5% rented the land for seasonal use (Figure 4.18)
In 1990 a number of people started farming within the wetland, this number has been increasing steadily through to the year 2005 and due to some of the joined efforts by Non Governmental Organizations and Community Based Organisations the number started to reduce upto the year 2014 when only 10 individuals started farming within the wetland areas. This results can also be supported by change detection images where there was a 65% increase in the areas cleared for cultivation in the area. Population increase can also be a major contributor to the same since increase in population directly leads to an increase in the areas for settlement and areas of agricultural purposes (Figure 4.19)

![Bar Chart](image)

Figure 4.19: The number of individuals farming within the Yala wetland

Evidence of clearing of the wetland for agricultural and settlement areas was evident in the area as presented in Plate 4.1. The methods used in clearing of the wetland were as given in Figure 4.21; burning which is thought to be the cheapest
and most efficient method had the highest percentage at 41% and was most preferred. Cutting /slashing of the wetland resources with a percentage at 32% was second, this is considered not efficient and tedious to the respondents. Though 14% of the residents prefer uprooting of the wetland vegetation as a better method; 13% of those interviewed use all the methods to clear land for cultivation and settlement purposes.

Plate 4. 1: Burning and cutting as methods of clearing of the wetlands
Figure 4.20: Clearing methods preferred by the residents for clearing the Yala wetland

The field survey given in Figure 4.22 indicate that most of the residents at 85% view that usable land within the wetland is at a higher risk of depletion as compared to papyrus which had a rank of 72%. Sedges was given a rank of 42%, fish 40% while thatching grass at 32% which could be attributed to the modernisation in the methods of thatching in the area. Livestock feeds were ranked at 21%, *synodon* at 8% and *sesbania* at 12%. 
Studies have revealed that the lakes fisheries are dominated by cichlids, particularly *Oreochromis esculentus* in Lake Kanyaboli and *Oreochromis niloticus* in Lake Sare. These species are slowly disappearing due to overfishing in the lakes; according to Lihanda et al.(2003) there are about 130 fishermen in Lake Kanyaboli operating 56 fishing vessels, mostly of “sesse” type and a few dugout canoes, the main gear being hooks, gillnets and traps. Some of the fishing boats in Lake Kanyaboli are shown in Plate 4.2.
4.2.3 Testing of hypothesis HAO2
Using the total percentage change in population and in land uses a T-test was calculated using the null hypothesis HAO2; a P-value of 0.9126 was obtained. The hypothesis spatiotemporal characteristics of population growth in the study area have direct linkages on land use land cover changes in the Yala wetland was therefore accepted.

4.3 Sustainable Measures for Utilizing Wetland Resources to Reduce Environmental and Socio-Economic Impacts in Yala wetland

According to the results in Figure 4.22 aquaculture had overwhelming support of 38%, this could be attributed to the fact that agriculture is considered the main economic activity in the area and integration of agriculture within the uses and protection of the wetland resources was deemed perfect.
Figure 4.22: Most preferred Sustainable measures by the respondents for Yala wetland and wetland resources uses.

Thirty three per cent of the residents supported tourism as an activity that can be practised in the area. Tourism creates employment and they would be able to provide for their families. Papyrus based industry development had a 20% support while only 9% of the respondents felt that policy implementation was a better approach.

4.3.1 Papyrus based industry

Twenty per cent of the respondents were for the idea that papyrus based industries would help in conservation of the wetland resources (Figure 4.22) because it would lead to creation of employment and the products would be sold to other areas increase the income levels of those in the industry. The rest at 80% had reservations that this industry would need to be controlled and would be seasonal and depending on the availability of papyrus. Though this industry is been
practiced by the residents, it is not controlled and the products generated

Plate 4.3: Pictures showing some products made from the papyrus reeds

4.3.2 Aquaculture
Most of the respondents 38% ranked aquaculture as the best way to sustainably use the resources in the wetland (Figure 4.22). This is due to the fact that most of the residents depend on agriculture as the main socio economic activity to sustain their livelihood. Aquaculture integrates the two, (agriculture and fishery) they felt like to would have the least impact on their sources of livelihood and at the same time it would help in conservation of the wetland.

Dominion farm, a large scale farm in the area is practicing fish farming and crop production (rice). Several fish ponds have already been constructed within the farm as well as fish cages within the section of Lake Kanyaboli which is within the farm. There is evidence of a fish hatchery with fingerlings (Plate 4.4). The farm has a fish breeding done using tanks, hapas and ponds (Plate 4.4)
4.3.3 Tourism

Tourism is the least developed activity at present. This was rated the second at 33% of the respondents (Figure 4.2). Tourism is believed to be a creator of employment and income generator. Potential tourist attractions include bird watching, sport fishing and boating. Further income could be obtained by charging the tourists visiting the wetland. The wetland could be promoted as a locally controlled, people–centred tourist destination and be included in Kenya’s ‘western circuit’. Finally, the success of an integrated natural resource management depends on developing and implementing a comprehensive management plan drawn up by all the stakeholders. Yala Swamp is recognized as one of Kenya’s 60 Important Bird Areas (Awange and On’gan’ga, (2006); Bennun and Njoroge,(1999).

The swamp also provides a habitat for several bird species that are papyrus endemics such as the White-Winged Warbler (Bradypterus carpilis), Papyrus
Yellow Warbler (*Chloropeta gracilirostris*) and Papyrus Gonolek (*Laniarius mufumbiri*) (Kenya Wetlands Forum 2006, Mavuti, 1992). The wetland also has a variety of fish species; these include three species of tilapia: *Oreochromis esculentus*, *Oreochromis leucostictu* and *Oreochromis variabilis* and several haplochromine cichlids species which include *Astatoreochromis alluaudi*, *Lipochromis maxillaris*, *Astatotilapia nubile*, *Xystichromis phytophagus* and *Lipochromis maxillaris* (Abila *et al*, 2008). The critically endangered Sitatunga antelope (*Tragelaphus spekei*) still lives in the wetland system’s papyrus vegetation (Abila, 2002). Although sport fishing has not been fully developed, there are indicators the activity could be developed further. Plate 4.5 shows some of the endemic birds’ nests in the study area.

Plate 4. 5: Bird nests in the Yala wetland

Case study of the Nepal wetlands was conducted by BirdLife International which is a Ramsar International Organisation Partners implemented a Darwin Initiative project by Bird Conservation Nepal (BirdLife Partner) at Koshi Tappu Wildlife
Reserve (KTWR) a Ramsar site and Important Bird Area in Nepal which is demonstrated the importance of a range of ecosystem services provided by the site, such as providing food, fibre, groundwater recharge and spiritual experience. (Kenya Wetlands Forum, 2006). As part of the study, nature-based tourism was valued at $121,000 for 2010–11. This benefit was received mainly by the local lodges and their employees, though significant revenue has received directly by the reserve from entrance fees. If this can be applied in the Yala swamp environs then it is bound to have good economic value to the residents.

4.3.4 Policy implementation
Policy implementation had the least support from the respondents at 9%. This is due to the fear of the residents that policies would be too strict and eventually limit and control how the wetland is been utilised by the residents. It would also lead to unnecessary arrests and prosecution by the implementing bodies. Those who supported the policy implementation and all stakeholders should be included in the policy making process and especially the community who are the directly affected individuals so that the policies are accommodating and inclusive. Yala wetland is not among the protected wetlands in the country and thus has been facing serious problems of degradation. There has been large-scale conversion of wetlands to agricultural land. While not easy to perceive, the conversion has also implied that nature’s capacity of reduction and retention of nutrients has diminished.
The areas for policy intervention from the study should first be introduced to address the constraints that inhibit accumulation of livelihood assets and secondly, to capitalize on those positive forms of institutions both at micro-, meso- and macro-levels to enhance the status of wetlands, improve resource use efficiency and increase agricultural productivity. Despite controversies facing the swamp, the first reported reclamation actually took place in one part of the swamp, commonly known as area 1, from the mid-1960s to early 1970s, in which 2,300 ha of swamp was drained, under a project sponsored by UNDP and FAO (OSIENALA, 1998).

Reports, though, indicate that swamp reclamation resulted in ecological problems, such as lower water quality in Lake Kanyaboli, decreased species diversity and increased pressure on resources of the remaining wetland (OSIENALA, 1998). Investigations by Schuijt (2002) and Abila (1998) further indicated that the local community was the net loser from the reclamation; the benefits forgone from their use of wetlands far outweighed what they obtained in the new situation. Despite this, new proposals have been developed and feasibility studies conducted for further reclamation and development of parts of the remaining wetland (OSIENALA, 1998). While reclamation has received immense political support, past studies indicate that this has been a source of conflict with the local communities.
CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the results above Yala swamp wetland has increasingly been facing serious problems of degradation the wetland has reduced by 33.17% between 1990 and 2014. There has been large-scale conversion of wetlands to agricultural as evident from the field surveys where the number of individuals clearing land for farming within the wetland was on an upward trend up to the year 2005 where the number reduced due to the involvement of the NGO’s and CBO’s. The high levels of poverty and continuous population growth seem to be the main contributors to the wetland degradation and unsustainable use. This is largely because conversion of wetlands to uses other than conservation is determined by household pursuit of welfare improvement, which in turn, is influenced by households’ asset position and vulnerability shocks as demonstrated in this study the population increase in the study area is more to blame for this degradation.

Though it seems impossible to reclaim the wetland to its original status study suggests that there are sustainable ways in which the wetland and its resources can be used so as to maintain a stable environment where the population and wetland coexist sustainably, some of the suggested activities that the researcher deemed suitable were aqua agriculture, tourism, papyrus harvesting and bee
keeping. This is not all but if practiced with good supervision they can help in maintaining balance between the wetland and the increasing human population.

The foregoing demonstrates that like most tropical wetlands, the Yala Swamp wetland is important for its biodiversity and is of great socioeconomic value to the local community. Long lasting sustainable utilization, conservation and management strategies of this resource therefore hinge on addressing the seemingly conflicting demands of biodiversity conservation, community utilization and agro industrial development.

The high economic potential of the Yala swamp wetland, the wetland being non-protected area and the lack of a proper wetland policy makes the Yala Swamp vulnerable ecosystem. While reclamation has received immense political support, past studies indicate that this has been a source of conflict with the local communities. Conversion of the wetland to agricultural farms, while it may give short term gains, will lead to long term economic, social and environmental problems such as inflated costs of living and reduction of yields of crop yields after irreversible soil fertility exhaustion. Evidence on the ground indicates that other problems associated with conversion such as resettlement, compensation, sedimentation, eutrophication and habitat loss have not been adequately addressed in the on-going Yala Swamp irrigation development scheme.
5.3 Recommendations and Future Research

5.3.1 Recommendations

In order to realize effective management of the wetland resource and reduce the degradation rate at which it is undergoing, following recommendations are suggested.

- The local community be involved in restoration and reclamation of the degraded wetland some of the activities may include papyrus planting and stakeholders and professionals to train them on better sustainable utilization of wetlands.

- The Government should do more Investment in wetland management. The government main investment should be through policy implementation and enforcement of the laws and policies that are already in place, such as tourism marketing, aquaculture programs and development of a controlled papyrus industry.

- All stakeholders should support coordinated wetland management this can be done through involvement of community based organizations that are tasked to implement sustainable utilization of resources. They should be supported by the government and international Non-Governmental Organizations such as the UNEP

5.3.2 Future research

The present study has shown that some issues require further consideration:
o Climate change is a global problem that should be addressed by small actions done locally. Yala wetland is susceptible to ecological effects caused by climate change. The researcher suggests that studies on the management of Yala swamp in the face of climate change be undertaken, this will help in understanding that not only anthropogenic activities cause change in the wetland but also nature through climate change does, this will lead to development of all inclusive management strategies for the wetland.

o Studies on environmental valuation (including indirect and non-use values) in wetland management of Yala wetland ecosystem should be conducted. This may assist in assessing trade-offs between maintenance of intact wetland against its conversion into other uses. Such investigation will ensure that the broadest implications of any further conversion of the swamp are fully understood to better so that the wetland are managed sustainably.

o Studies on appropriate environmental management and utilization policies are developed that will be enforced on Yala wetland and other riparian areas in Kenya as a whole should be undertaken. This study will be geared towards development of appropriate policies, implementers and bodies to ensure implementation to the latter. Community participation should be core to ensure that future conflicts among communities, development partners and the government are minimized.
REFERENCES


KNBS (1990), Kenya National Bureau of Statistics


KNBS (2010), Kenya National Bureau of Statistics


APPENDICES

Appendix 1: Land use decisions and socio economic Questionnaire

Part I: Background information

|-------------------|-----------------------|-----------------------|-----------------|----------------|-------|

7. What is the role of the respondent in the household?
   a. Household head [ ]
   b. Husband [ ]
   c. Wife [ ]
   d. Child [ ]
   e. Worker [ ]
   f. Other (specify) .................................................................

Household information

<table>
<thead>
<tr>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11.</th>
<th>12.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>Sex/ gender</td>
<td>Marital Status</td>
<td>Type of marriage</td>
<td>Level of education</td>
</tr>
<tr>
<td>1=Male</td>
<td>2=Female</td>
<td>1=Married</td>
<td>2=Polygamous</td>
<td>1= None</td>
</tr>
<tr>
<td>3= Widowed</td>
<td>3=Inheritance</td>
<td>2=Lower Primary( Std1-3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4= Divorced</td>
<td>4= Others</td>
<td>3= Upper primary(Std4-8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5=Other(specify)</td>
<td></td>
<td>4= Post primary training</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5=Secondary( Form 1-4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6=Post-secondary training</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7=Middle level colleges</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>8= University</td>
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</tbody>
</table>

79
13. A part from farm income, do you have another source of income?

14. If yes, from which source and how much per year?

<table>
<thead>
<tr>
<th>Source</th>
<th>Tick</th>
<th>Returns (Ksh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1] Petty Trade</td>
<td></td>
<td>1= &lt;1000</td>
</tr>
<tr>
<td>[2] Remittances</td>
<td></td>
<td>2= 2,000-5,000</td>
</tr>
<tr>
<td>[3] Interest from shares/savings</td>
<td></td>
<td>3= 6,000-10,000</td>
</tr>
<tr>
<td>[4] Brewing</td>
<td></td>
<td>4 = &gt;10,000</td>
</tr>
<tr>
<td>[v] Mat making</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[vi] Rope making</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[vii] Boda boda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[viii] Tailoring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[ix] Casual labour(Amal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[x] Leasing out land</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[xi] Bar wa bar (leasing)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

16. Land ownership

<table>
<thead>
<tr>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you have land for use</td>
<td>Property rights/tenure</td>
</tr>
<tr>
<td>1=Yes 2=No</td>
<td>1=Family land 2=Bought 3=Inherited 4=Rented</td>
</tr>
<tr>
<td>Family land</td>
<td>Bought</td>
</tr>
<tr>
<td>Bought</td>
<td>Inherited</td>
</tr>
<tr>
<td>Inherited</td>
<td>Rented</td>
</tr>
</tbody>
</table>

17. Which year did you start farming in the wetland?

........................

18. When you started farming in the wetland, did you clear the land yourself or had it been farmed before you started using it?

19. If the answer to Qn. 18 is [1] which method did you use for land clearing in the wetland?

1= Uprooting [....]
2= Burning [....]
3= Cutting/slashing [....]
4= All above [....]

20. In your view, rank in the table below in order of severity the resources above that are in danger of depletion?

[1] = Extremely depleted (80%) [2] = severely depleted (75%)
[5] = Slightly depleted (10 - 30%) [6] = Not depleted (0 - 9%)
[7] = Don’t know

<table>
<thead>
<tr>
<th>Wetland resource</th>
<th>Rank</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>[i] Usable Land in wetland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[ii] Papyrus (Oundho)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[iii] Sedges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[iv] Fish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[v] Thatching Grass (See)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[vi] Vossia Sp -Saka- (Livestock feed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[vii] Synodon D. (Modhno)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[xi] Sesbania S. (Omburi)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

21. What are some of the measures that can be taken to sustainably use the wetland and its resources?

1. Aquaculture ( )
2. Tourism ( )
3. Papyrus ( )
4. Policy implementation ( )

Appendix 1: Original 1990 Landsat image of the Yala wetland and its environs

Appendix 2: Original 2000 Landsat image of the Yala wetland and its environs
Appendix 3: Original 2010 Landsat image of the Yala wetland and its environs

Appendix 4: Original 2014 Landsat image of the Yala wetland and its environs
Appendix 3: Clipped images for years 1990, 2000, 2010 and 2014

Appendix 5: Clipped 1900 image of the Yala wetland and its environs

Appendix 6: Clipped Image 2000 of the Yala wetland and its environs
Appendix 7: Clipped Image 2010 of the Yala wetland and its environs

Appendix 8: Clipped Image 2014 of the Yala wetland and its environs