Sustainable Management of Natural Wetlands in Urban Areas: Case of Dunga Swamp, Kisumu, Kenya

Project Report

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of

Masters in Urban Management

By

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DECLARATION

I hereby declare that this project is my original work and has never been submitted for the award of a degree in any university. All cited pieces of work from other Authors to enhance this work have been recognized in the references.

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This research was carried out and submitted for examination with my approval as the university supervisor.

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DEDICATION

To God, to my dear Wife Rinny and Son David.

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LIST OF ACRONYMS AND ABBREVIATIONS

CBD: Convention on Biological Diversity

CBNRM: Community Based Natural Resource Management

CBOs: Community-Based Organization(s)

CPR: Common Pool Resources

EIA: Environmental Impact Assessment

EMCA: Environmental Management and Coordination Act

ESAs: Ecologically Sensitive Areas

ETM: Enhanced Thematic Mapper

ETM+:   Enhanced Thematic Mapper plus

FAO: Food and Agriculture Organization of the United Nations.

GIS: Geographical Information System

GoK: Government of Kenya

IBA: International Bird Association

IUCN: International Union on Conservation of Nature

KFS: Kenya Forest Services

KNBS: Kenya National Bureau of Statistics

KWF: Kenya Wetlands Forum

KWS: Kenya Wildlife Services

LBDA: Lake Basin Development Authority

LUP: Land Use Plans

LVB: Lake Victoria Basin

LVBC: Lake Victoria Basin Conservation

LVEMP: Lake Victoria Environmental management Programme

MDGs: Millennium Development Goals

MEA: Millennium Ecosystem Assessment

NEMA: National Environment Management Authority

NGOs: Non-Governmental Organization(s)

QGIS: Quantum GIS

ROI: Region of Interest

SL: Sustainable Livelihoods

TM: Thematic Mapper

UNCCD: United Convention to Combat Desertification

UNCED: United Nations Conference on Environment and Development

UNEP: United Nations Environmental Programme

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ABSTRACT

The concern that human settlements can have direct and indirect impacts on the environment, and that wetlands are particular susceptible to negative change, has long been proven. It is for this reason that this study was conducted to establish the anthropogenic causes leading to degradation of Dunga Swamp in the context of sustainable urban wetland management. Specifically, the study sought to: (1) review and map out the degradation of Dunga Swamp in the urban context, (2) establish the causes of the degradation of Dunga Swamp with a view to bring out their management implications and (3) develop a framework for sustainable management of urban wetlands.

The study was based on a combination of research instruments, chief among them being Remote Sensing and GIS. Other research instruments included field observations and interviews. Key informants selected on predetermined criteria were interviewed.

From the study it was established that, Dunga Swamp had reduced by 64.8% from 1990 to 2011 and that the remaining percentage is heavily fragmented. Major causes of this degradation were found out to be construction on the wetland, burning of the swamp, excessive unsustainable harvesting of papyrus reeds and poor management of swamp. From the findings a sustainable management framework was formulated.

The study concluded that natural wetlands are valuable assets in our nation which requires an understanding of the dynamics of human and environmental parameters at play to manage them effectively and efficiently.

In light of this, the hypothesis that poor management of human settlements in urban areas leads to degradation of wetlands was accepted.

<center>**CHAPTER ONE**</center>

1.0 INTRODUCTION

1.1 Background

Wetlands located in urban areas play vital roles as they are most needed in these environs due to the relatively high concentration of human population. According to Ramachandra et al. (2012) and Schuyt (2005), land use changes in these areas have, however, led to a significant loss in these ecosystems. Many wetlands world over have been converted to non- wetland uses through filling, drainage, pollution and over exploitation of resources found in these ecosystems.

While these concerns are global and not spatially isolated to one region or nation, the scale and intensity of the problems vary from region to region in as much as common set of issues can be identified. It is worth noting that environmental problems are basically social beginning with people as the cause and ending up with people as the victims (Pavan Kumar et al, 2010).

Chabwela (1998) and Kachali (2008) reckons that wetlands have always been perceived as waste lands and the land and water of wetlands particularly in Africa have been converted to other uses such as agriculture and infrastructure. Although alterations have often been thought to be in the best interest of society the environmental costs of wetland loss have been high.

In view of the above stated costs, wetlands have recently become the subject of increasingly heated debate. Many people prefer converting them to other uses for commercial purposes while others want them left in their natural state because they believe that wetlands are vital ecosystems on Earth. LVBC (2011) noted that many wetland habitats converted into uses such as agriculture, urban development or other forms of human settlements may yield greater productivity in the shorter term but if not sustainably developed, may result into greater long term losses in productivity. While the role of wetlands in supporting community livelihoods and enhancing resilience cannot be over-emphasized, the degradation of many wetlands in Kenya is a cause to worry.

According to (LVEMP, 2014), wetland resources Management requires collaborative efforts among the various actors of the Government, Non-State Actors, Media, local communities

and institutions working towards the achievement of sustainable development. Based on this notion, the Environmental Management and Coordination Act of 1999, has provided substantial provisions and opportunities for conservation and sustainable management of wetlands in Kenya. For instance sections 42, 54 and 55 particularly, have provided the need for sustainable wetlands, marine and coastal resource management In addition, the subsidiary legislations (regulations) such as the Environmental Management and Coordination (EIA/Audit) regulation of 2003 and the Environmental Management and Coordination (Wetlands, Riverbanks, Lakeshore and Seashores Management) Regulations of 2009 among others, have further stressed sustainable development within and around wetland areas through development control and gazettement of wetlands as protected and conservation areas.

An important step forward was when Kenya ratified the Convention on Wetlands of International Importance (Government of Kenya, 2013) in 1990. The convention obligates contracting parties to "formulate and implement their planning so as to promote the conservation" of wetlands. Moreover, the Government of Kenya through the Ministry of Environment, Water and Natural Resources produced the Kenya Wetlands Atlas which maps the country's major wetland resources. A master plan for the conservation and sustainable management of water catchment areas in Kenya was also developed to guide practical and transformative actions for the sustainable management of these complex ecosystems.

The Kenya wetland atlas and the protection of water catchment areas are part of the mutually reinforcing policy publications geared towards addressing severe degradation of the country's wetlands and also ensure sustainable management of these resources (NEMA 2013a). While launching the publications the Cabinet Secretary for the Ministry of Water, Environment and natural Resources reiterated that Wetlands are a key resource in the Country's socio-economic development and the attainment of vision 2030 (NEMA, 2013a). However, many are in danger of disappearing due to human population pressure, urban growth, infrastructure development and also unplanned settlements. UNEP postulates that Kenya has extra ordinary wetland system that will continue to function or cease to function in the near future based on their management or mismanagement (NEMA, 2013b). Kenya presently has six sites designated as wetlands of international importance with a surface area of 265,449 hectares which include; Lakes Baringo, Bogoria, Elmentaita, Naivasha, Nakuru and Tana Delta (NEMA, 2013b).

Even though not included in the list of wetlands of international importance, from ecosystem to socio-economic perspectives, Lake Victoria as a whole can be recognised as an ecologically sensitive area (ESA) due to its mosaic habitats (wetlands, forested areas, rivers and river mouths, rocky shores and outcrops) that provide ecosystem services (LVBC 2011). In all there are at least 422 wetlands occupying an area of 4,322 km2 around Lake Victoria (417km^2 in Kenya, 1880 km^2 in Tanzania and 2025 km^2 in Uganda). In all these about 3% of wetlands in the vicinity of urban centres are in the highly degraded and highly threatened ESAs category. Of these wetlands, Dunga Swamp in Kisumu city is one of the largest wetland (1.036 km^2) that are classified as highly degraded and highly threatened.

The wetland is situated about 10 km south of Kisumu town on the shores of Winam Gulf, Lake Victoria. At the western limit is a beach, used as a major fish landing point. Papyrus *Cyperus papyrus* stands stretch south-eastwards along the shore from here for approximately 1.5 km, in a strip that varies in width from about 50 to 800 m. The swamp is predominantly Papyrus *(Cyperus papyrus)* which forms distinctive habitat type for papyrus specialist birds. The birds include the restricted range endemics like the globally threatened Papyrus Yellow Warbler *(Chloropeta gracilirostris),* the near threatened Papyrus Gonolek *(Linarius mufumbiri)* ,inter alia.

In line with this, the main objectives of this study were to develop a sustainable management framework for Dunga Swamp while analysing the extent of the degradation and major threats. Ultimately, it is hoped that sustainable management and utilisation of Dunga Swamp resources will be realised and consequently, the economic well-being of Kisumu City and the local community in particular.

1.2 Statement of the problem

The hypothesis that human settlements can have direct and indirect impacts on the environment, and that wetlands are particular susceptible to negative change, has long been proven (Maltby, 1986). Yet despite this, the march of human settlements continues to destroy and degrade natural capital more so in urban areas.

According to LVEMP (2014) Natural wetlands provide a variety of natural products to rural communities living around Lake Victoria, Kenya, ranging from papyrus biomass which has multiple and gender-specific uses, to food products such as fish and seasonal crops. They are

also important habitats of plant genetic diversity and support large numbers of bird, mammal, reptile, amphibian, fish and invertebrate species. However the increasing human population, coupled with unsustainable exploitation and conversion has led to a decline in wetland goods, particularly fisheries and loss of other vital ecosystem services.

Much research has been carried out on Dunga Swamps and it emerges that the wetland is highly threatened and endangered largely because of human settlements and activities. A local NGO sponsored by Wetlands International, Eco Finder, postulates that because of human settlements, the Northern and Eastern parts are drying up while the swamp is encroaching into the lake in the southern part. Many plants and animal species in the wetlands have been lost while others still thriving are in the danger of losing their habitat. Dunga Swamp plays a vital role to the local community especially as a fish breeding ground, source of papyrus and tourism, among other roles.

If this trend continues, many residents of Kisumu city will suffer especially the urban poor who strongly depend on the natural resources like Dunga Swamp for livelihood. Therefore sustaining the use and management of this wetland forms a cost effective strategy for sustainable human settlements in Kisumu city with strong benefits for poverty reduction and biodiversity conservation.

It is due to the foregoing that this research was conducted to determine and establish the best management practices that will enhance sustainable utilization of Dunga swamp resources in the rapidly urbanizing Kisumu City. The findings and recommendations may form a basis for informing decision makers, residents and other stakeholders in urban wetland management and sustainable wetland resource use.

1.3 Objectives of the study

The overall objective is to establish the anthropogenic causes leading to the degradation of Dunga Swamp in the context of sustainable urban wetland management.

Specific objectives include:

1) To review and map out the degradation of Dunga swamp in the urban context
2) To establish the causes of the degradation of Dunga Swamp with a view to bring out their management implications.
3) To develop a framework for sustainable management of urban wetlands

1.4 Hypothesis

Alternative hypothesis

Poor management of human settlements in Kisumu City has lead to degradation of Dunga Swamp.

Null hypothesis

Poor management of human settlements in Kisumu City has not lead to degradation of Dunga Swamp

1.5 Justification

Managing human settlements and the natural environment poses challenges to urban managers in the contemporary world and indeed since the inception of urbanization. As human settlements expand it is usually so at the expense of the environment. Towards this end, settlements are usually more pronounced in urban areas thus the greatest degradation of the natural environment. Of these natural environments, wetlands are termed the most vulnerable. In real sense the most threatened ecosystem in the world.

Many wetlands in the tropical regions have not been adequately studied as compared to those in the temperate regions (FAO, 1998). Further on Wetlands research in Kenya has mostly been concentrated in lacustrine wetlands of the rift valley formation (Kelebogile, 2005). While wetlands around Lake Victoria have been studied, a majority of the studies have not been focusing on sustaining wetlands as a resource in urban human settlements. However due to rapid urbanization, especially in Africa, the ever increasing human pressure on these ecosystems cannot be overlooked. It is worth noting that urbanization is unstoppable and as Linda McDowell (1981) argues that if the 19th century was referred to as the century of industrial revolution, then the twentieth century might equally as well be dubbed as the century of urban revolution

It is also worth noting that in recent times, wetlands have assumed new attraction and value as potential settlement areas and waste disposal sites due to their relative levelness and their perceived worthlessness as well as a host of other uses in urban areas. This has rendered wetlands to be truly threatened landscapes and ecosystems. Wetlands need to be appreciated and conserved for their traditionally perceived values and hydrological- physical, biological and socio economic functions.

Various studies have been carried out on the benefits and threats on Dunga Swamp (Kairu, 2001, IBA 2010, Jernsand and Kraff 2013, Raburu 2005, Mafabi 2000) yet no management strategies and conservation measures have been formulated. For instance, Mafabi (2000) reckons that land use activities around wetlands of Lake Victoria are dominated by cultivation, livestock grazing and settlements which are a threat to their existence but offers no suggested mitigative measures.

This study sought to determine a framework that can result in the marriage of these two contemporary world developments thus sustainable management of wetlands as a resource in sustainable human settlements in urban areas.

Findings may be used to inform the public and decision makers on importance of sustainable utilization of wetland resources as well as pointing out gaps that were not filled by this study for further action.

The study focused on Dunga swamp located in Nyalenda sub location and the settlements there in such as Dunga village. Impacts of these settlements on the swamp in terms of land use change, area change were evaluated and a sustainable land use framework/ management plan developed.

1.6 Scope and limitations of the study

The study focused on human settlement and activity impacts on Dunga Swamp. Whereas human settlements and activities have impacts on wetland area/ extent, water quality and quantity as well as flora and fauna, only the changes in Dunga Swamp area/ extent were evaluated.

It should be noted that focus was on Dunga natural swamp hence no attention was paid on any constructed wetland within the study area.

During the analysis of satellite imageries, data gap on the 2010 Land sat imagery prompted the use of 2011 satellite imagery in the former's place even though the study sought to use satellite imageries at a 10 years interval basing on 1990. The data gap was as a result of radiometric errors that were difficult to correct and at the same time achieve the level of accuracy required during data analysis of acquired satellite imageries.

It is true that wetlands are affected by other factors such as climate change among others that may not necessarily be within the wetland itself. However, as regards this study only anthropogenic activities within the wetland were evaluated.

1.7 Operational definitions

Ecosystem: A specific biological community and its physical environment, interacting to produce an exchange of matter and energy, comprise an ecological system. An ecosystem may be large, such as a forest, or very small, such as a pond or even the surface of a person's skin.

Urbanization: The increase in proportion of people living in towns and cities and the ways in which they adapt to the changes.

Sustainable human settlements: An integral approach in which provision of infrastructure for human settlements is environmentally sound.

Land use: The purpose for which land is used. A more detailed description provided by FAO (1995) states that "land use concerns the function or purpose for which the land is used by the local human population and can be defined as the human activities which are directly related to land, making use of its resources or having an impact on them".

Wise use of wetlands; Ramsar (1987) defined wise use of wetlands as "their sustainable utilisation for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem".

Biosphere: is a planetary life support system extending from the bottom of the oceans to the upper limits of the troposphere (the lowest layer of the atmosphere). It is a large scale system of integrated parts that contains and sustains life.

Anthropogenic: of, relating to, or resulting from the influence of human beings on nature.

Fragile environment: A fragile environment is an ecosystem or community which lacks resilience or which is so heavily impacted by an 'un-natural' (generally human) event that it changes in unexpected and undesirable ways. Any definitions of fragility must be relative to the normal disturbance regime which that community would be expected to encounter. Disturbance regimes cover a spectrum which includes small frequent events and everything up to extreme uncommon events. All communities and ecosystems are vulnerable or fragile to some extent. Recognizing the limits is the key to understanding and management.

Wetland: any land that is flooded shallow water all or most of the time.

Federal definition of wetlands is "Those areas that are inundated or saturated by surface or ground water 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. Wetlands generally include swamps, marshes, bogs, and similar areas." (Environmental Laboratory, 1987)

Degradation: In this Study the word was taken to mean reduction in environmental resource quality and swamp area.

Philosophy: the line of thinking that shapes and guides a research.

1.8 Structure of the report

Chapter one delt with introductory part of the research including background information, statement of the problem, justification, objectives and hypothesis. Chapter two was on review of existing literature on wetland definition, classification and effects of human activities on them from a global perspective narrowing down to the study area. In addition literature on wetland management and gaps was assessed. In Chapter three, background information on the study area and a map was provided as well as methodologies that were used in the study including: sampling, tools of data collection and analysis as well as the conceptual framework that guided the study. Chapter four focused on data analysis and discussions while chapter five dwelt on summary of the study findings, conclusion and recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Of interest for this thesis were topics related to wetland resources management in urban areas and sustainable use of wetlands. This chapter focused on wetland definition and classifications. A review of the relevant literature on these thematic areas provided theoretical and empirical background to the study objectives mentioned in the previous chapter. In addition the role of Remote Sensing and GIS in management of wetlands and urban human settlements were discussed.

2.2. Definition of Wetlands

The Ramsar Convention on Wetlands produced an international, intergovernmental treaty which defined wetlands somewhat broadly. Thus wetlands include "*areas of marsh, fen, peat land 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"* (Ramsar, 2011). The area of land covered by this treaty was later expanded in Article 2, providing that wetland areas … "*may incorporate riparian and coastal zones adjacent to the wetlands and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands.*"

This served as the foundational definition of the term "wetland" in the thesis in order to best encapsulate wetlands on a global scale.

In Kenya, wetlands are defined as areas *of land that are permanently or occasionally water logged with fresh, saline, brackish, or marine waters, including both natural and man-made areas that support characteristic plants and animals.* These include swamps, marshes, bogs, shallow lakes, ox-bow lakes, dams, riverbanks, floodplains, fishponds, lakeshores and seashores. In addition are the coastal and marine wetlands such as deltas, estuaries, mud flats, mangroves, salt marshes, sea grass beds and shallow reefs all of which at low tide should not exceed 6 meters. These wetlands occupy about 3% to 4%, which is approximately 14,000 km2 of the land surface and fluctuates up to 6% in the rainy seasons (government of Kenya, 2013). The Environmental Management and Coordination Act (EMCA, 1999), which is Kenya's framework environmental law defines wetlands simply as 'areas permanently or seasonally flooded by water where plants and animals have become adapted.'

2.2.1 Classification and mapping of wetlands

Classification of wetland types can be a very in-depth and complicated process, because the more one considers the variations in wetland characteristics, the more categorizations can be created. However, such in-depth processes would be outside the scope of this paper. There are four main types of wetlands in a basic system of classification i.e swamp, marsh, bog, and fen (Keddy, 2000). The following descriptions are based upon a synopsis of literature by Keddy (2000) and Moore (2008):

Swamp- A wetland community dominated by trees with a developed leaf canopy, which have invaded from nearby areas into herbaceous marshes and fens, rooted in hydric soils, but not peat; Examples include tropical mangrove swamps and bottom-land forests in floodplains.

Marsh- A wetland community dominated by herbaceous plants, usually emergent through water and rooted in hydric soils, but not peat; Examples include cattail marshes around the Great Lakes, reed beds around the Baltic Sea and papyrus reeds around Dunga Swamp Kisumu

Bog - A wetland community dominated by sphagnum moss, sedges, ericaceous shrubs or evergreen trees rooted in deep, sometimes uncompacted peat; Examples include blanket bogs which cover mountain sides in Europe and floating bogs which cover the shores of many lakes in temperate and boreal regions.

Fen- A wetland community usually dominated by sedges and grasses rooted in shallow peat, often with considerable water movement through the peat; Examples include the extensive peatlands in northern Canada and Russia, as well as smaller seepage areas throughout the temperate zone."

Basing on this classification, Crafter *et al* (1992) grouped tropical wetlands into 8 classes namely Marine, Riverine, Lacustrine Palustrine, Deltaic, Plateau, Montane and Constructed wetlands based on topography and hydrological conditions. A wetland classification system for East Africa (Howard, 1996) recognizes 22 specific habitat types, 16 of which are linked to inland waters.

In general wetlands in the Lake Victoria Basin fall in the categories of riverine, lacustrine and deltaic. Still in some areas we find plateau and constructed wetlands (ponds and irrigated land). These wetlands are characterized by the changing hydrological regimes around the Lake where rainfall seasonality leads to heavy and low river flow. They also experience short-term changes in nutrient supply through seasonal flooding which leads to changes in the structure of plant and animal communities. This transitional nature makes it difficult for one

to precisely delineate their boundaries (Raburu, 2005). Therefore in accordance to Keddy's (2000) classification, Dunga wetland in Kisumu is categorised as a swamp.

Fig 2.1: Map on Wetlands of Kenya

Source: Kenyan Wetlands Atlas, 2013

2.2.2 Wetland resources in Dunga Swamp

Dunga swamp is a natural wildlife habitat for a variety of plants and animals some of which are of conservation significance including endemic, endangered and migratory species. The swamp is also in-situ bank for genetic resources. It holds eight out of Kenya's nine Lake Victoria biome bird species, including the globally-threatened Papyrus Yellow Warbler. Because of its size and the generally good condition of the papyrus, Dunga Swamp is an important site for East Africa's papyrus endemics. These include Papyrus Yellow Warbler, Carruthers's Cisticola, White-winged Warbler and Papyrus Canary. Many other wetland birds also occur (Britton 1978, Nasirwa & Njoroge 1997). However no information is available on other wildlife species present in the swamp even though wetlands around the shores of Lake Victoria are known to be important refuges for a number of the lake's endemic haplochromine fish species (IBA 2010).

Table 2.1: **Bird and Plant species in Dunga Swamp**

	English name	Scientific name	Local name
1	White egret	*Ardea ibis*	Okok
2	Ducks	*Alopochen spp.*	Atudo
3	African Fish Eagle	*Haliaeetus vocifer*	Ongo
4	Sacred ibis	*Bostrychia hagedash*	Ngaga
5	Grey crowned crane	*Balearica pavonina*	Ongowang
6	Kingfisher	*Halcyon chelicut*	Kirindi
7	Weaver bird	*Ploceus spp.*	Osogo
8	Swallows	*Hirondo spp.*	Opija
9	Cormorant	*Phalacrocorax spp.*	Osou
10	Pelican	*Pelecanus spp.*	Mbusi
11	Vultures	*Gyps spp.*	Achuth

12	Heron	*Ardea spp.*	Nyamnaha
13	Plover	*Vanellus*	Orwenda
14	Fan tailed widow bird	*Euplectes axilliaris*	Oseng
15	Northern red bishop	*Euplectus orix*	Oseng
16	Coucal	*Centropus sp.*	Tutu
17	Robin chat	*Cossypha sp.*	Hundhwe
18	Pied wagtail	*Motacilla sp.*	Onchinyo
19	Doves	*Turtur spp.*	Akuru
20	Hamerkop	*Scopus umbretta*	Anam
21	Black kite	*Milvus migrans*	Otenga
22	Black- necked Grebe	*Podiceps nigricollis*	Hudiwiri
23	Yellow Wabler		
24	Papyrus	*c. papyrus*	Thin/ Ogada
25	Reeds	*Phragmites sp.*	
26	Hippo grass	*V. cuspidate*	
27	Ambatch tree	*Aeschynomene elaphroxylon*	Orindi
28	Cat tail	*Typha domingensis*	

Source: LVBC, 2011

2.3 Anthropogenic impacts on wetlands

Today, as more than half of the world's population lives in cities and urban areas, managing and developing urban areas is one of the main challenges of the developing world. Of the

major challenges include achieving a balance between sustainable human settlements and environmental conservation.

Verhoeven and Setter (2009), reckons that for years, wetlands have been considered as wastelands only fit for reclamation and disposal of waste. Throughout human history, wetlands have been and are still being reclaimed for agriculture and construction in many parts of the world. Ecosystems reclaimed in this way loose much of their character, leading to reduced biodiversity and reduced performance of functions other than crop productivity and construction purposes (Hassan *et al*., 2005). For the global resource of freshwater wetlands, it is certain that substantial wetland areas have been lost because of drainage and development. About 50% of the area of peat lands, depressional wetlands, riparian zones, lake littoral zones and floodplains have been lost, mostly through conversion to intense agricultural use, in North America, Europe and Australia (MEA, 2005).

However, the extent of impacts on African wetlands are unknown because data is limiting (MEA, 2005), but threats abound as can be evidenced by a number of studies in the Lake Victoria Basin (Kairu, 2001; Balirwa, 1998). In the last fifty years, wetlands in the LVB have been facing serious problems of degradation and their ability to continue providing valuable ecological services is threatened (Kairu, 2001, Kansiime *et al*., 2007).

The main driver of changes in Lake Victoria ecosystem are human population pressure, especially its increasing size, rapid growth rate and increasing urbanization and immigration. In the upper reaches of many rivers, the main threats to wetlands are reclamation for agriculture, overgrazing, human settlement and encroachment, siltation, pollution (mainly from agriculture and industrial sources), introduction of exotic species such as blue gum trees (*Eucalyptus* spp.) and overharvesting of water dependent plants.

Socio-cultural factors, such as traditions, lifestyles and informal natural resource abstraction by local communities have also influenced perception of wetlands, their use and management. Lack of adequate and appropriate knowledge about the functions and values of wetlands have hindered active management, including rehabilitation of degraded areas by local communities.

Among the major threats facing Dunga Swamps and wetland resources are human settlements and construction, drainage, clearing, filling and reclamation for subsistence crop production and overgrazing. Exploitation of papyrus plants is sometimes done unsustainably (Morrison

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et al., 2012) and this has led to complete loss of some parts of the wetland and causing cascading negative impacts on wide range of biodiversity in these important ecosystems. Past aerial surveys on changes in papyrus cover around the lake shows a remarkable loss. A comparative aerial survey between 1969 and 2000 showed 50% loss in Dunga and 47% and 34% loss in Koguta and Kusa respectively (Mafabi 2000). Papyrus height and density are inversely related to human disturbance including footpaths, cutting, burning, grazing and farming (Owino, 2005).This argument is reinforced by Mafabi (2000) who states that land use activities around wetlands of Lake Victoria are dominated by cultivation, livestock grazing and settlements which are a threat to their existence.

According to IBA (2010), Dunga is close to a major town, and this puts particular strain on the wetland. Papyrus harvesting is often excessive and unsustainable. The incoming streams bring pollution in the form of sewage and solid wastes from nearby residential estates.

2.4 Wetland management

Wise use has been widely recognized as a central tenet of sustainable development in wetland management throughout the world. In 2005 the concept of wetland wise use was incorporated into the Millennium Ecosystem Assessment (MEA) framework to highlight the importance of maintaining a balance between wetland utilization and maintenance of ecosystem diversity. However, the implementation of this framework has been less than effective due to inadequate official government support in terms of institutional and organisational arrangements and lack of local community engagement.

According to Ramsar (2011), the development and implementation of a wetland management and planning process should involve all stakeholders, and that such management planning processes should be applicable to all wetlands, irrespective of whether they are Ramsar designated or not.

In addition Ramsar Convention urges states to recognize that wetlands, through their ecological and hydrological functions, provide invaluable services, products and benefits enjoyed by, and sustaining, human populations. Therefore, the Convention promotes practices that will ensure that all wetlands, and especially those designated for the Ramsar List, will continue to provide these functions and values for future generations as well as for the conservation of biological diversity.

To this end, the two concepts of wise use and site designation are fully compatible and mutually reinforcing. Contracting Parties are therefore expected to designate sites for the list

of Wetlands of International Importance on account of their international significance in terms of ecology, botany, zoology, limnology or hydrology and to formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and as far as possible the wise use of all wetlands in their territory.

On this account, Ramsar (1987) defined wise use of wetlands as "*their sustainable utilisation for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem*". This in environmental terms equates to sustainable use and management.

Therefore, an important component of wetland protection and management is to identify what wetland functions need to be protected, and which wetlands need additional protection because they have other important characteristics (Amanda et al, 1997).

Wetland functions can be grouped into three broad categories: water quality improvement, hydrologic functions, and habitat functions. Each of these can be further divided into more specific functions. For example, habitat functions can be divided into habitat for amphibians, habitat for mammals, etc.

In addition to identifying what functions need to be protected, managing wetlands requires an understanding of how the functions are performed. Wetlands in each hydrogeomorphic class perform a particular set of functions; some are the same and some are different from wetlands in other classes.

Understanding how each function operates and how human activities can affect that function is critical to determining the appropriate type and level of protection and management that will be achieved through comprehensive plans, critical areas ordinances, and other regulations, as well as non-regulatory tools.

The two most common methods for protecting wetland functions have been the use of buffers and compensatory mitigation. Buffers are used to maintain existing functions by reducing the impacts of adjacent land uses. When impacts to wetlands are unavoidable, replacement of lost functions has typically been through compensatory mitigation in which other wetlands are created, restored, or enhanced using specific ratios based on area.

According to NEMA (2012), the key to sustainable management of wetland ecosystems is availability of relevant information and data. This notion is further expounded by Salum (2007) who postulates that wetland management involves valuing local knowledge without ignoring scientific knowledge. Thus using both types of knowledge, a balance can be established where users and conservers can achieve compromises on what should and should not be done for the sake of the wetlands.

Generally speaking, wetland degradation is, to a larger part, influenced and shaped by the actions of people, especially during the use and production processes. When no precise rights are placed on wetlands, they become accessible to everyone and are quickly degraded. It is also argued that wetland conservation is a complicated task that requires input from different resources, each playing its own but coordinated role. Furthermore, it is perceived that wetland destruction is a process that, to the majority of local people, is unintentional. In most cases, people cannot even realize what causes rivers to dry up, or why they harvest less food. But again, wetland management can also be a conscious, intentional process that is planned and implemented. Therefore, it is the responsibility of conservers to recognize that the destruction of wetlands can be an unintentional process and to consider this in their conservation plans. That means knowledge gaps have to be filled by acknowledging that users have to be well informed and educated about which actions cause wetland destruction. This could involve knowledge dissemination while maintaining people's right to resource use but in an optimal manner.

Another approach is referred to as Community-Based Natural Resource Management (CBNRM) which has demonstrated its prospect in development projects. Several studies have argued that CBNRM is effective than other approaches (top-down, command-and-control, systematic science and technology-based management systems) in terms of decision-making, distributional implication, coping with uncertainty, learning and adaptation, and sustainability (Ostrom 1990; Ostrom et al. 2002).

2.4.1 Land Use Change and wetland management

According to (Meyer, 1995) land use change is the change in land cover and land use. Land cover is the physical state of the land surface which includes both natural amenities (crop lands, mountains, vegetation, soil type, biodiversity, water resources) and man-made structures (buildings, pavements). Given that land use refers to the way human beings employ and exploit land cover for several purposes (Lambin et al., 2006, p. 216; Meyer, 1995) such as farming, mining, housing, logging, or recreation. Then land use change is the exploitation of land cover through its conversion and/or modification over time primarily to serve human needs.

It is evident that property rights or lack thereof have an impact in livelihood strategies and consequently on the wetland ecosystems. The wetland and water resources are essentially Common Pool Resources (CPR), defined by Ostrom et al 1990 and Kachali, 2008) as"

resource systems regardless of the property rights involved". They include "natural and human constructed resources in which (i) exclusion of beneficiaries through physical and institutional means is especially costly, and (ii) exploitation by one user reduces resource availability for others". This means that more and more users can come into wetlands and extract resources in a manner that is not sustainable without any repercussions.

Though wetlands play an important role in livelihood activities of many urban communities, these activities are not benign but have an impact on wetland ecosystems and its functions. In addition, "at the root of wetland conversion is the fact that numerous stakeholders of wetlands with different interests lay claims on the wetlands' water and lands that do not always coincide" (Schuyt 2005). Stakeholders may include direct extensive users, who directly harvest wetland goods in an unsustainable way; agricultural producers that drain and convert wetlands to agricultural land; indirect users that benefit from indirect wetland services, such as storm abatement and flood mitigation; nature conservation and amenity groups, whose objective is to conserve nature and enjoy the presence of plant and animal species; and even nonusers that may attribute an intrinsic value to wetlands" (Schuyt, 2005). In many cases, it is likely that the different interests of these stakeholders conflict so that conservationists are faced with complex trade-offs.

2.4.2 Wetland management in Kenya

Wetland management in Kenya is implemented through a wide range of policies, legislations, regulations, standards and institutions established for the purpose of wetland and environmental management in the country. According to NEMA (2008, pp 16), most of the instruments have evolved from important Global fora such as the Stockholm Conference on human Environment of 1972, UN conference on Environment and Development (UNCED) of 1992 and most importantly the International Convention on wetlands of international Importance(Ramsar) of 1971.

Kenya ratified the Ramsar Convention on 5th October 1990 and has designated six wetlands listed as Wetlands of International Importance which include; Lakes Nakuru, Naivasha, Baringo, Bogoria, Elementaita and Tana Delta.

Kenya Constitution 2010

The Constitution of Kenya recognizes the environment as a national heritage and promotes its sustainable management for the benefit of present and future generations. Matters regarding the environment are interspersed in the Constitution in Article 10 (2) (d) on sustainable development, Article 42 on the right to a clean and healthy environment and Chapter 5 on Land and Environment. Article 69 specifically provides the obligations of the state and all persons with respect to the environment.

Environmental management and coordination Act (EMCA) of 1999

The National Environment Management and Co-ordination Act (EMCA), was expected to harmonize all the statutes, legal frameworks and legislations that concerned environmental issues.

The Act provides for the establishment of an appropriate legal and institutional framework for the management of the environment and for the matters connected therewith and incidental thereto. Section 9(1)) established the National Environmental Management Authority (NEMA) which has the mandate of ensuring overall coordination, planning, regulation, and enforcement of environmental standards as well as overall compliance with this Act.

Section 42 provides for the conservation and protection of the environment with a specific bias towards wetlands.

In addition, the subsidiary legislations (regulations) such as the Environmental Management and Coordination (EIA/Audit) regulation of 2003 and the Environmental Management and Coordination (Wetlands, Riverbanks, Lakeshore and Seashores Management) Regulations of 2009 among others, have further stressed sustainable development within and around wetland areas through development control and gazettment of wetlands as protected and conservation areas.

However the Act as well as subsidiary legislations, does not wholly prohibit construction on wetlands nor does it prevent private ownership of wetlands. This would be important because the major threat of wetlands is construction activities and land subdivisions.

Various Land Acts

There are four new land legislations enacted to give effect to the provisions of the Constitution and the National Land Policy, namely the Land Act, the Land Registration Act, land court Act and the National Land Commission Act. Another proposed legislation on community land is yet to be enacted

Provisions of Land Act and the National Land Commission Act are of relevance to this wetland management plan.

The Land Act seeks, among other things, to provide for the sustainable administration and management of land and land based resources. It reinforces the principles of land policy set out in the Constitution. Section 11 of the Act empowers the National Land Commission to take appropriate action to maintain public land that endanger endemic species of flora and fauna, critical habitats or protected areas and to identify ecologically sensitive areas that are within public lands and demarcate or take any other justified action on those areas and act to prevent environmental degradation and climate change subject to consulting with existing conservation institutions. The Commission shall also make rules and regulations for the sustainable conservation of land based natural resources that include measures to protect critical ecosystems and habitats.

The National Land Commission Act provides for the functioning of the National Commission established by Article 67 of the Constitution. Among its functions is to monitor and have oversight responsibilities over land use planning throughout the country.

The water Act of 2002

It transformed the institutional framework for water governance by establishing a number of institutions for the management of water and sanitation including water catchment areas of which wetlands are part of.

It is important to note that, the Act does not define 'wetlands' nor does it make any direct reference to wetlands. However, its definition of "water resource" ("any lake, pond, swamp, marsh, stream, watercourse, estuary, aquifer, artesian basin or other body of flowing or standing water, whether above or below ground") clearly encompasses wetlands. Two outstanding features of the Water Act that are of relevance to the discussions about wetlands are, firstly, its streamlining of different functions related to the sustainable management of

water resources; and secondly, its provisions of a framework for participation of different stakeholders in the management of water resources.

The Forest Act

It too does not specifically deal with wetlands. The Act establishes the Kenya Forest Service (KFS), the functions of which include, "managing forests on water catchment areas primarily for purposes of water and soil conservation, carbon sequestration and other environmental services". It empowers the Minister, upon the recommendation of the forest conservation committee for the area within which a forest is situated, the local authority and the Board of Kenya Forest Service to declare as a local authority forest any land under the jurisdiction of a local authority that is an important catchment area, a source of water springs, or is a fragile environment; or is rich in biodiversity or contains rare, threatened or endangered species". These powers can be used to conserve and protect wetlands.

Other acts that may be of relevance in managing wetlands include, the Physical Planning act of 1999, wildlife conservation Act, Public health Act, agricultural Act (cap 318) and the Fisheries act, among others

Policies on wetland management and conservation

According to LVEMP (2013), the key challenge in thinking about a National Wetland Policy is how to reconcile the need for specific attention, which drives the quest for a stand-alone policy on wetlands with the fact that wetlands constitute components of ecological systems, so that their sustainable conservation and management is only possible within the overall framework of environment and natural resources management. The policy imperatives that inform the management of land, water, forests, and biodiversity, among others, have a direct bearing on the opportunities for proper management of wetlands.

In this regard, the Kenyan government has formulated a wide range of policies for sustainable development and environmental conservation as discussed below.

Draft National Wetlands Conservation and Management Policy

The draft Policy recognises that sustainable management of wetlands continues to face a myriad of challenges including reclamation and encroachment for agriculture, settlement and industrial development; invasive and alien species; pollution and eutrophication.

The Policy seeks to secure and ensure the benefits of wetlands for posterity and provides the framework for tackling wetland threats. It also aims at providing a framework for mitigating the diverse challenges that affect wetlands conservation and wise use in Kenya. It's also vital for the country to fulfil its obligations under the Ramsar Convention and other relevant Multilateral Environmental Agreements. Thus it sets out the following objectives: 1. enhance and maintain functions and values derived from wetlands 2. establish an effective and efficient institutional and legal framework 3. improve scientific information and knowledge base on Kenyan wetland ecosystems. 4. strengthen institutional capacity on conservation and management of wetlands 5.To promote innovative planning and integrated management approaches 6. promote communication, education and public awareness and 7. promote partnership and cooperation at regional and international levels .

National Land Policy of 2007

The aim of the National Land Policy is to guide the country towards efficient, sustainable and equitable use of land for prosperity and posterity. The National Land Policy highlights the need for policy responses to poor environmental management and inappropriate ecosystem protection and management. It recommends policy responses that include adoption and implementation of Land Use Plans (LUPs). It outlines principles to guide the protection of watersheds, lakes, drainage basins and wetlands. These include: prohibition of settlement and agricultural activities in water catchment areas; identification, delineation and gazettement of all water courses and wetlands in line with international Conventions; and integrated resource management based on ecosystem structure regardless of administrative or political boundaries.

National Water policy of 1999

The Policy tackles issues pertaining to water resources management, water and sewerage development, institutional framework and financing of the water sector.

The policy advocated for the review of Water Act Cap 327 resulting in the current water Act of 2002

Multilateral Environmental Agreements (MEAS)

At International levels, Kenya is party to a wide range of the above stated agreements that affect environment and to an extend the wetlands especially on Land Environment, Marine environment, Atmosphere, biodiversity, wastes and chemicals among others.

Of particular importance as cited earlier in this study is the convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar). Other important agreements that may (though indirectly) concern wetlands include; the Rio Declaration and Agenda 21, the United Nations Convention to Combat Desertification (UNCCD), and the Convention on Biological Diversity (CBD).

The Ramsar Convention, which is the only global environmental treaty that deals with wetland ecosystems, came into force in December 1975. Kenya ratified the Convention on 5th October 1990 and has 6 wetlands listed as Wetlands of International Importance, including Lakes Nakuru, Naivasha, Baringo, Bogoria, Elementaita and the Tana Delta.

Although Dunga Swamp has not been designated as a wetland of International Importance, it still plays a vital role in direct and indirect provision of resources to local residents of Kisumu city and even beyond. Therefore it needs to be protected, conserved and sustainably managed for prosperity and posterity.

2.4.3 Key gaps in wetland management strategies in Kenya

As stated earlier on the two most common methods for protecting wetland functions, as accepted globally, have been the use of buffers and compensatory mitigation. Buffers are used to maintain existing functions by reducing the impacts of adjacent land uses. However when impacts to wetlands are unavoidable, replacement of lost functions has typically been through compensatory mitigation in which other wetlands are created, restored, or enhanced using specific ratios based on area. These methods are considerably lacking in wetland management in Kenya. While the National draft policy on wetland management is explicit on buffering, mitigation measures have not been highlighted. Even so buffering of nearly all wetlands in Kenya including those of International importance is lacking.

(Schuyt, 2005) suggests that in many cases, it is likely that the different interests of wetland stakeholders conflict so that conservationists are faced with complex trade-offs. In real sense wetland management requires strong consideration of existing land tenure system. In cases of

private ownership, many property owners tend to convert wetlands to housing as has been in Pipeline, Nairobi and indeed in many urban and peri-urban wetlands as these fetch more returns for them directly. However wetland play crucial role to many urban residents indirectly including flood controls and recharge of water table. The draft Wetland management Policy has captured this issue which was previously lacking.

Many of the policies on Land and natural resources management apart from the draft wetland policy have poor consideration of wetlands as part of decision making in Environmental conservation. In many cases wetlands are hardly mentioned. Furthermore existing land regulations tend to favour those who want to convert other than traditional wetland users, most of who are poor. Mwakubo (undated) sums up this issue, thus "areas for policy intervention would be first to address the constraints that inhibit accumulation of livelihood assets. Secondly, to capitalize on those positive forms of institutions both at micro and macro-levels to enhance the status of wetlands, improve resource use efficiency and increase agricultural productivity. The envisaged policy implication is to take into account household welfare besides institutional innovations and hybridisation as part of the policy package towards sustainable use of wetlands.

This should also take into account local reasons for overreliance on wetland products.

Wetlands can be productive if local management institutions are dynamic and take into account shocks that impinge on households in addition to livelihood assets. 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 (Mwakubo, undated). From much of the literature it emerges that many communities in Kenya are not aware of the importance of conserving these ecosystems. This attribute is further expounded by (Ostrom et al 1998: 278, Kachali, 2008) who argue that wetland and water resources are essentially Common Pool Resources (CPR) and Salum (2007) who states that wetland destruction is a process that, to the majority of local people, is unintentional. Therefore, it is the responsibility of conservers to recognize that the destruction of wetlands can be an unintentional process and to consider this in their conservation plans. That means knowledge gaps have to be filled by acknowledging that users have to be well informed and educated about which actions cause wetland destruction. This could involve knowledge dissemination while maintaining people's right to resource use but in an optimal

manner. Indeed this aspect has been captured as a policy statement in the draft National wetland Management and Conservation Policy (Government of Kenya, 2013).

In addition to this point the literature suggest that incorporation of Local administration in conservation wetlands is wanting. The draft Policy suggests inclusion of County governments but previously local Administration should have been utilised to conserve wetlands.

Furthermore there seems to be impartial treatment of wetlands management in Kenya, thus preferential treatment and much government involvement in some wetlands such as kingwal, Ondiri and a host of others while many small and scattered wetlands especially in urban areas are neglected. According to Ramsar (2010) management and planning processes should be applicable to all wetlands, irrespective of whether they are Ramsar designated or not.

2.5 Sustainable wetlands management tools

In accordance with NEMA (2012), deviations from the hypothesized normal conditions in wetland characters are predicted to have an effect on the ecological processes and functioning of wetlands. Overall changes in wetlands can be reflected on resources that comprise and determine its functioning, including water quality, biodiversity, human dependence (sociocultural and economic values) and landscape settings. During wetlands research it is therefore advisable to identify which indicator resources or tools to use to determine whether a particular wetland condition has changed. Of reasonable importance is that strategies that monitor biological variables should also monitor other indicator variables e.g., water quality: temperature, pH, turbidity; socio economic; and land use/cover changes.

Geographical Information System (GIS)

GIS is becoming an increasingly useful tool in wetland management. In conjunction with remote sensing, GIS can play a major role in facilitating quick assessment of water pollution and wetland degradation. It also enables us to see and spatially model wetlands in the context of population clusters, transportation networks, and developmental activities etc, which influence the wetlands.

Some of the capabilities of GIS which are utilized in environmental management are: delineation of land use and land cover, overlay analysis, buffering, and thematic mapping.

Remote Sensing

In real sense Remote Sensing technologies provide the means to map the characteristics of a wetland area, and monitor its conditions at regular intervals, from a distance. As stated by NEMA (2012), a variety of remote sensing platforms and sensors are available offering products with a variety of spatial spectral (reflectance characteristics) and temporal resolutions (periods between data capture). Using remote sensing data, it is therefore possible to map or classify wetland features at a variety of time intervals and the track the changes therein.

For this research, GIS was combined with Satellite Imagery to track the possible changes in Dunga Swamp areal changes and trend from 1990 to 2011 in relation to growth of Kisumu City and adjacent settlements to the swamp. For specification, Landsat satellite imagery was utilised.

<div style="text-align:center">CHAPTER THREE</div>

3.0 RESEARCH DESIGN AND METHODOLOGY

This chapter focuses on the procedures that were used to guide the process of data collection, analysis and interpretation in order to answer the study objectives. In discussion are the research design, data collection instruments and procedures, and methods of data analysis.

3.1 Study area

The study focused on Dunga Swamp within Kisumu City boundaries and the resultant settlements within the swamp.

Fig 3.1 Location of Dunga Swamp in relation to Kenya and Africa
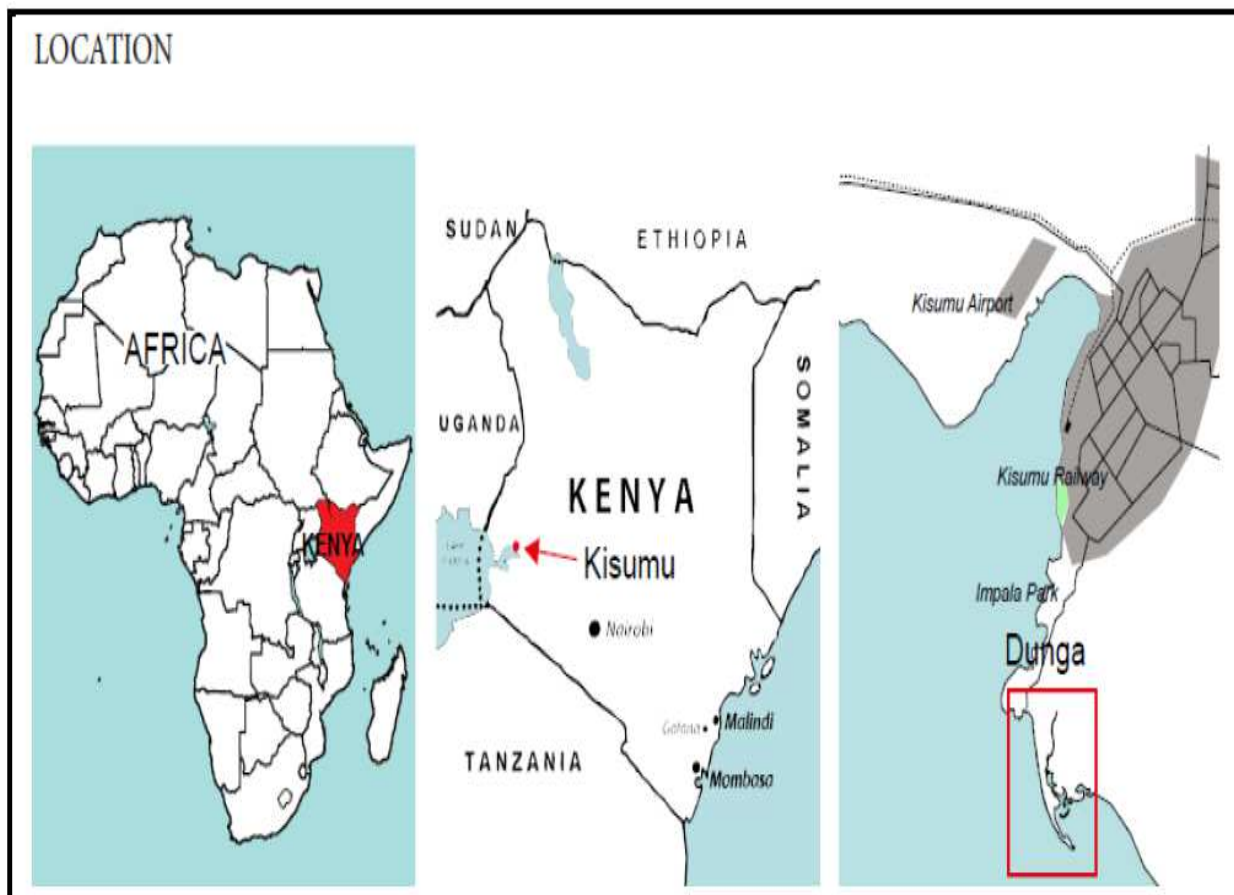
Source: Reddin & Wanga,(2012)

Fig 3.2: Map of Dunga Swamp
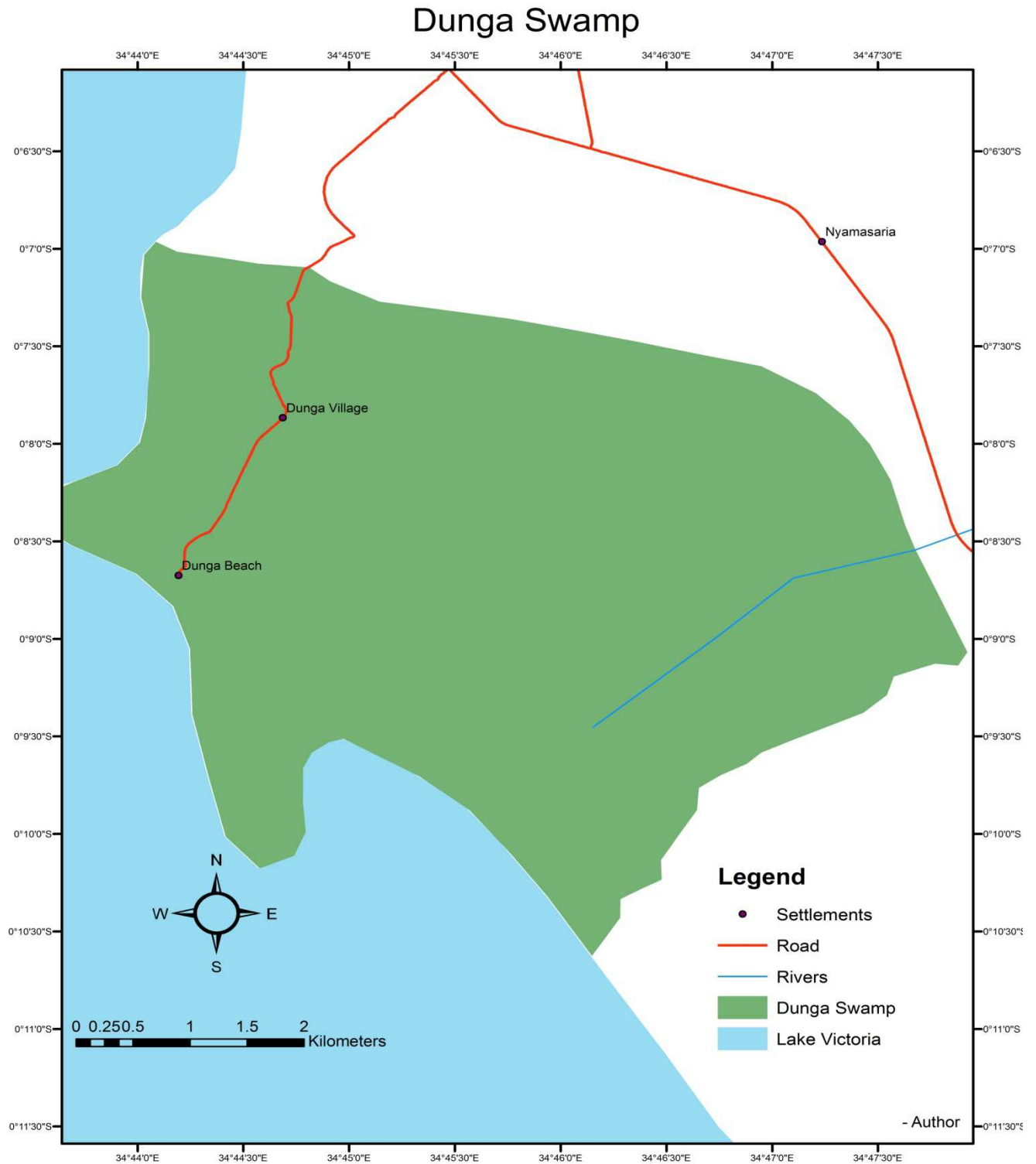
Source: Field Research

According to IBA (2010), Dunga swamp is situated about 10km south of Kisumu town stretching from the shores of Lake Victoria. The County City Planning Department confers that the Swamp is within Kisumu City boundaries. The Swamp covers an estimated area of 500ha at an altitude of 1130m. At the western limit is a beach (refered to as Dunga beach), used as a major fish landing site. Papyrus (*cyperus papyrus*) stands stretch south-eastwards along the shore for about 5km, in a strip that varies in width from about 50 to 800m. A number of streams drain their water into the lake through the swamp, the main one being Tako river.

Fig 3.3: Part of a stream traversing the wetland

Source: Field Research

Fig 3.4: The main road from Kisumu City to Dunga Village and Beach

Source: Field Research

The swamp is predominantly Papyrus (Cyperus papyrus) which forms distinctive habitat type for papyrus specialist birds. The birds include the restricted range endemics like the globally threatened Papyrus Yellow Warbler (Chloropeta gracilirostris), the near threatened Papyrus Gonolek (Linarius mufumbiri), White Winged Warbler (Bradypterus carpalis), Carruthers's Cisticola (Cisticola carruther) and Papyrus Canary (Serinus koliensis) and also the endangered antelope species, the Sitatunga. It is also a very prominent habitat for nesting and rearing of chicks to the endangered African grey crowned crane. More so, the swamp is (1) an important habitat and breeding ground for most Lake Victoria indigenous fish species e.g. the lungfish, mudfish and tilapia; (2) a buffer/filter of pollution entering Lake Victoria the second largest fresh water lake after Lake Superior in Canada; (3) It's a potential site for eco-tourism due to its diverse plant and animal species for bird and botany as well as its other aesthetic values.

Within the swamp is found a village called Dunga village. According to KNBS 2009 population census the human population was estimated at 30,500 people. The village is largely dominated by the Luo community. However, the Luhya and Kisii tribes from the adjacent western province are residents too. There exist some adjacent settlements around Dunga Swamps such as Nyalenda A and Nyalenda B as well as part of Nyamasaria settlements.

Fig 3.5: Map of Dunga Swamp and Administrative boundaries

Dunga Swamp and Sub-locational Boundaries
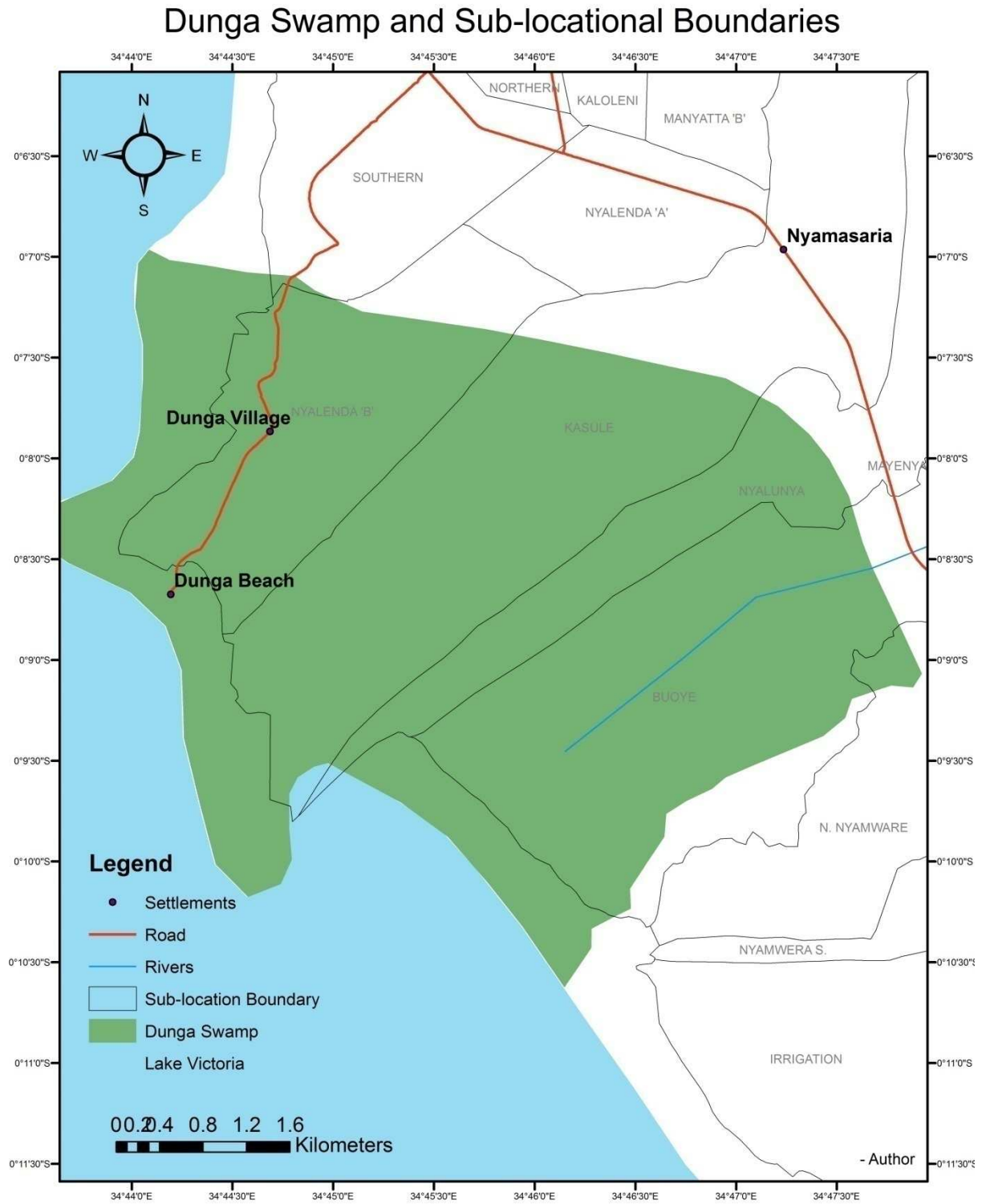
Source: Field Research

Land use activities at Dunga are dominated by cultivation, livestock grazing, fishing and settlements. Fishing is a major livelihood of the Dunga community. Recent intensification of these activities has led to other forms of disturbance to papyrus swamps such as pollution, burning and papyrus harvesting. Furthermore, the dependence on the lake for fishing has been threatened by the fall in water levels and invasion of the lake by water hyacinth.

The swamp has traditionally been used, especially by the women, for the harvesting of papyrus for the local cottage crafts like mats, chairs and baskets. Today, papyrus conversion and degradation at Dunga appear purposeful, driven by demand for papyrus products used mainly by the local people for the cottage industry.

3.2 Research design

This section is a highlight of the inter-relations between the independent and dependent variables. For this study the independent variable was swamp area, while dependent variables were human activities and land use change.

Use of Landsat imagery was key in delivering the output that meets the study objective one on mapping the Swamp. The imageries were from 1990 to 2010 at a ten year period interval, however, due to data gaps in the 2010 imagery, a 2011 satellite imagery of same month was used. Utilizing Quantum GIS software, each of the three imageries underwent first unsupervised classification to determine the general land use classes in the study area and then supervised classification in order to show the two land uses of interest (i.e Urban area and the wetland) in major classes classified as: Swamp, built area, bare soil/cultivated land and water. The results from these were then exported to Arcview GIS software for area calculations. Finally using Microsoft Excel the areas were subjected to the image change detection process in order to determine the changes and the rate(s) of change and areas of each class during the study period.

Understanding Land use change and the effects required some historical information, which was achieved using qualitative and quantitative data collected through interview and group discussion with selected informants believed to have a good understanding of the issues of interest. To this end, detailed interviews were conducted with 5 selected key informants from the study area as well as five organisations that are mandated by existing policies and legislations in managing the swamp to collect the data required.

A purposive sampling technique, involving the targeting of individuals who suited the subject and nature of study using predetermined selection criterion, was used to select the participants in liaison with the village elders and a Non Governmental Organisations active in the study area. More so field observations were made to have better information about the nature of the various land use classes prevalent in the study area.

Table 3.1 Summary of research design framework

Variable to measure	Methods/Tools	Indicators
Landuse change	Remote sensing, GIS, questionnaires, interviews	-Encroachment into the Swamp -Acres of Swamp lost to development -Area of Swam
Causes of land use change;	questionnaires, interviews, field observations	Constructed area Land use intensity (in or bordering wetland)
Solutions to degradation of the wetland	questionnaires, interviews, field observations	-Sustainable Dunga Swamp management framework

3.3 Population sampling

Using predetermined selection criterion, a purposive sampling technique involving the targeting of individuals who suite the subject and nature of study, was used to select 5 participants through consultation with Elders living in the study area. In addition a key Non Governmental Organisation (NGO) in the study area called Pathfinder was also interviewed as well as KWS, Kisumu Impala Sanctuary, Kisumu City Planning Department, Kisumu County Physical Planning Department and NEMA, Kisumu Office. These are the Organisations that are mandated to manage the Swamp as revealed in the literature review discussed in chapter two of this study.

3.4 Research instruments

Use of Landsat imagery was key in delivering the output that meets the study objective one on mapping of the swamp. The imageries were from 1990 to 2011 at a ten year period interval. Interviews and field observations were utilized to acquire more data in supplement of remote sensed data. More so interviews and field observations were utilized to capture data that was used in formulating Dunga Swamp management framework as guided by the earlier reviewed literature so as to accomplish the study objectives two and three on causes of the degradation and sustainable wetland management framework.

3.5 Analytical framework

The remotely sensed data was analyzed using GIS software; specifically Quantum GIS. In this, each of the three imageries underwent first unsupervised classification to determine the general land use classes in the study area and then supervised classification in order to show the two land uses of interest (i.e Urban area and the wetland) in major classes as: Swamp, Built area, Bare soil/cultivated land and Water. The results from these were then exported to Arcview GIS software for area calculations. Finally using Microsoft Excel the areas were subjected to the image change detection process in order to determine the change and areas of each class during the study period.

Data generated from the interviews and field observations was analysed and presented in a discussion form and a table summarising the threats to the wetland and solutions formulated.

3.6 Conceptual framework

As guided by the research objectives, this study focused on developing a sustainable management framework for wetlands in urban areas. The effects on wetlands that occur due to urbanisation and may have negative impacts on wetlands include; land use change and increased human settlements and activities.

Therefore the conceptual framework was based on: key gaps in the National wetland management policies and legislation through literature review, causes of degradation of Dunga Swamp and suggestions on possible solutions. From this a sustainable Dunga Swamp management framework was formulated as shown in the diagram below:

Fig 3. 6 Summary of conceptual framework

Source of Threat ➡️ | Human activities and settlements, Poor urban wetland Management |

Impact ➡️ | Land use change |

Threat on Wetland ➡️ | Degradation of wetland- reduced swamp area |

Management gaps ➡️ | Evaluation of existing policies, legislations and wetland management strategies |

Solutions ➡️ | Map swamp to determine rate of reduction, interview and observe to determine causes on ground and acquire suggestions on possible solutions |

Management Strategy ➡️ | Formulate a sustainable management framework for the swamp |

CHAPTER FOUR

4.0 DATA ANALYSIS, PRESENTATION AND DISCUSSIONS

4.1 Introduction

Since the aim of the study was to develop a sustainable management framework through ascertaining effects of human activities on wetlands in terms of land use change and possible mitigation measures. Mapping of the study area was the first step to be done. This was followed by field survey to determine the causes of the degradation and to derive possible solutions that constituted the sustainable management framework.

4.2 Mapping of Dunga Swamp

The mapping exercise was carried out in successive steps that commenced with identifying the required land use classes through unsupervised classification, followed by supervised classification of four chosen classes of focus. This was repeated in all the three satellite imageries, the results of which were vectorised and the respective areas calculated. Accuracy for each satellite imagery analysed was assessed to minimise data gap and error as below discussed.

4.2.1 Analysis of satellite imageries used

To cover the intended period of study, different types of Landsat imagery originating from a number of sensors were used. Thus, land sat Enhanced Thematic Mapper (ETM) and Enhanced Thematic Mapper Plus (ETM+) beginning of 1990s, 2000 and 2011 respectively. Care was taken to ensure that cloud cover level of imagery utilised was below 30 percent.

Even though the study intended to utilise satellite imagery in 10 year period intervals, it was not possible to utilise the Landsat imagery for the year 2010 due to high cloud cover and other geo spatial data gaps (radiometric errors). This prompted utilisation of ETM+ Landsat imagery of 2011 in place of the 2010 ETM one.

Table 4.1: Details about the Landsat Imagery used for this study

Image	District/ County	Date of Acquisition	No of bands	Band combination	Sensor type	Spatial resolution	Unclipped scene area
Landsat 7	Kisumu County	August 1990	8	3, 2, 1 for natural colour, 4, 3, 2 for false colour	Enhanced Thematic Mapper(ETM)	30 meters	185 km by 180 km
Landsat 7	Kisumu County	August 2000	8	3, 2, 1 for natural colour, 4, 3, 2 for false colour	Enhanced Thematic Mapper (ETM)	30 meters	185 km by 180 km
Landsat 8	Kisumu County	August 2011	11	3, 2, 1 for natural colour, 4, 3, 2 for false colour	Enhanced Thematic Mapper plus (ETM+)	30 meters	185 km by 180 km

Fig 4.1: 2010 Imagery with intense radiometric errors

2010 imagery (unclassified)   2010 imagery
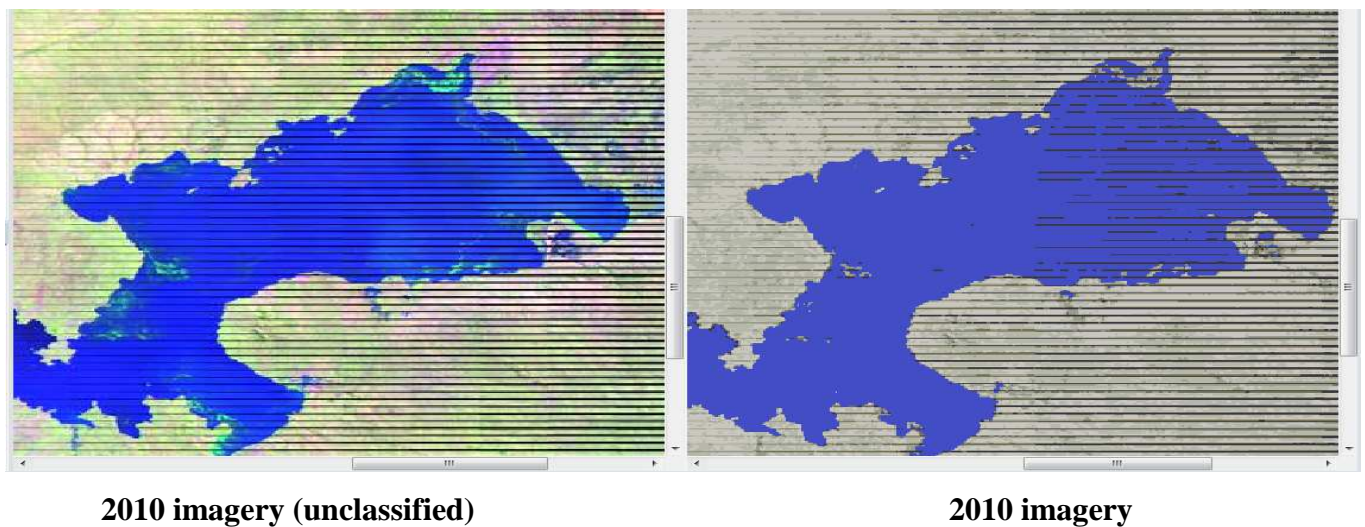
Source: Field Research

4.2.2 Imagery geometric correction and clipping

Once the imageries had been acquired, geometric corrections were performed using quantum GIS software to fit the imageries into the real world features in a process defined as geo referencing. To this end Geometric correction ensured perfect fit of imagery with related underlying shape files under similar spatial projection on the ground.

Fig 4.2: Landsat 2000 Georeferenced
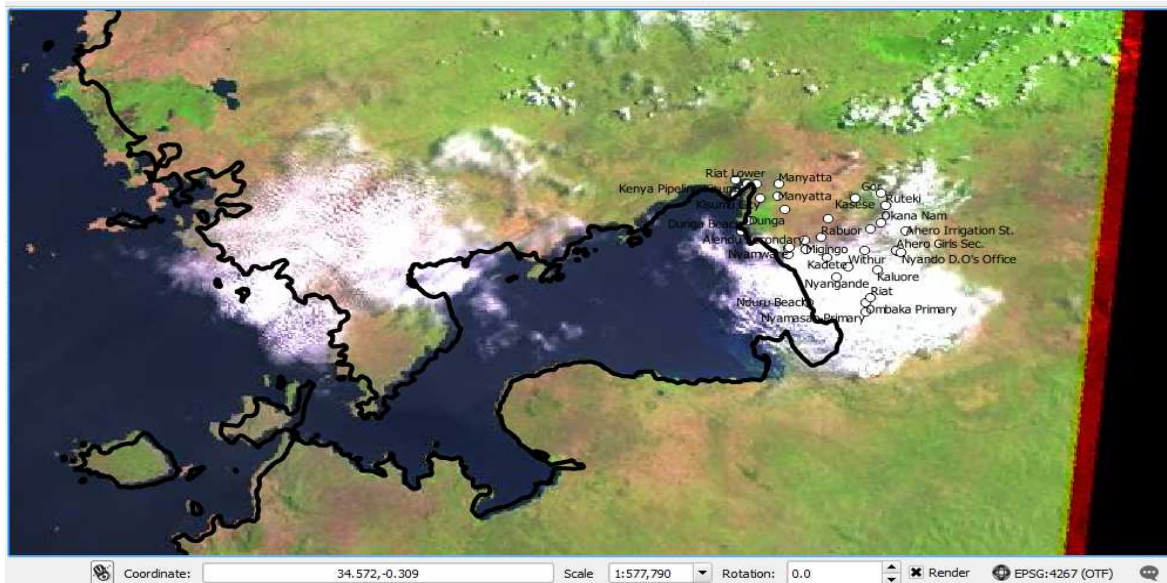
Source: Field Research

After the imageries had been Geo referenced, the next step was definition of regions of interest (ROI). This entailed selecting an area around the study area which had to be in a regular shape or polygon in accordance to GIS and remote sensing thumb of rule. In real sense this meant restricting the area of interest around Dunga swamp given that imageries acquired were far much larger than estimated study area. This was achieved by clipping the area of interest to 17.3 KM by 17.3 KM (73711 acres or 29484.54 ha) around the swamp for easy of area calculation in the vector analysis. For raster analysis no clipping was considered for the sake of accuracy assessment.

Fig 4.3: 17.3 by 17. 3 Kilometres clipping of Dunga Swamp study area
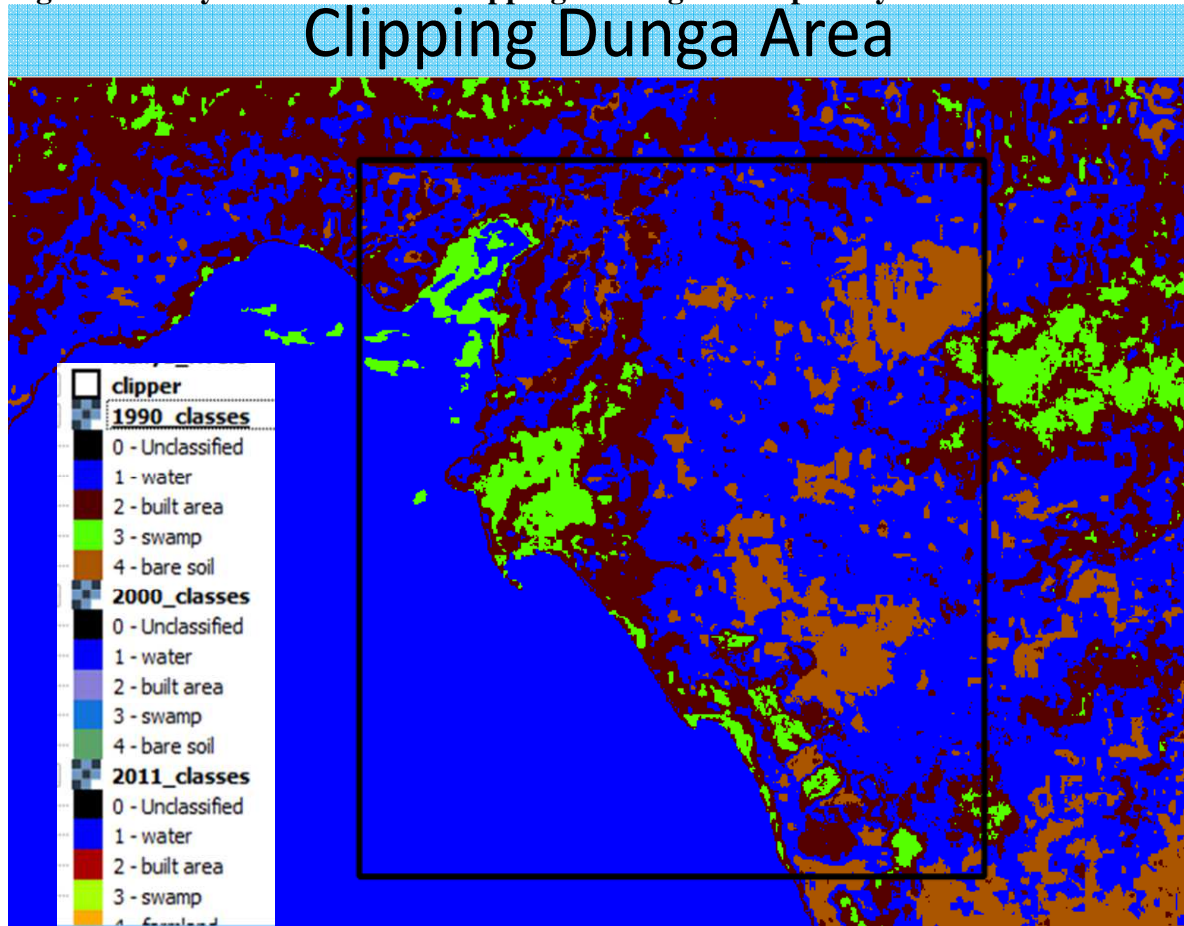
Source: Field Research

4.2.3 Determination of classes of focus in the Study Area

In identification of land use and land cover in any study using GIS and Remote Sensing, two popular approaches in image classification exist; supervised classification and unsupervised classification. In supervised classification, each pixel in an image is assigned to a user or analyst-defined land use/land cover type (residential, industrial, agriculture, forest, grassland, paved surface, etc.) depending on the homogeneity of that land use or land cover (peacock 2014). In unsupervised classification, Computer GIS software is instructed by the user or analyser to group similar pixels into various spectral classes which the analyst must then identify and combine into information classes.

For this study, in order to know the land use/ land cover classes prevalent in the study area, unsupervised classification was performed to determine the existing land use and land cover using 1990 as the base year. Six classes were revealed in accordance with the spectral reflection signatures as shown below:

39

Fig 4.4: Standard deviation plot for accuracy determination
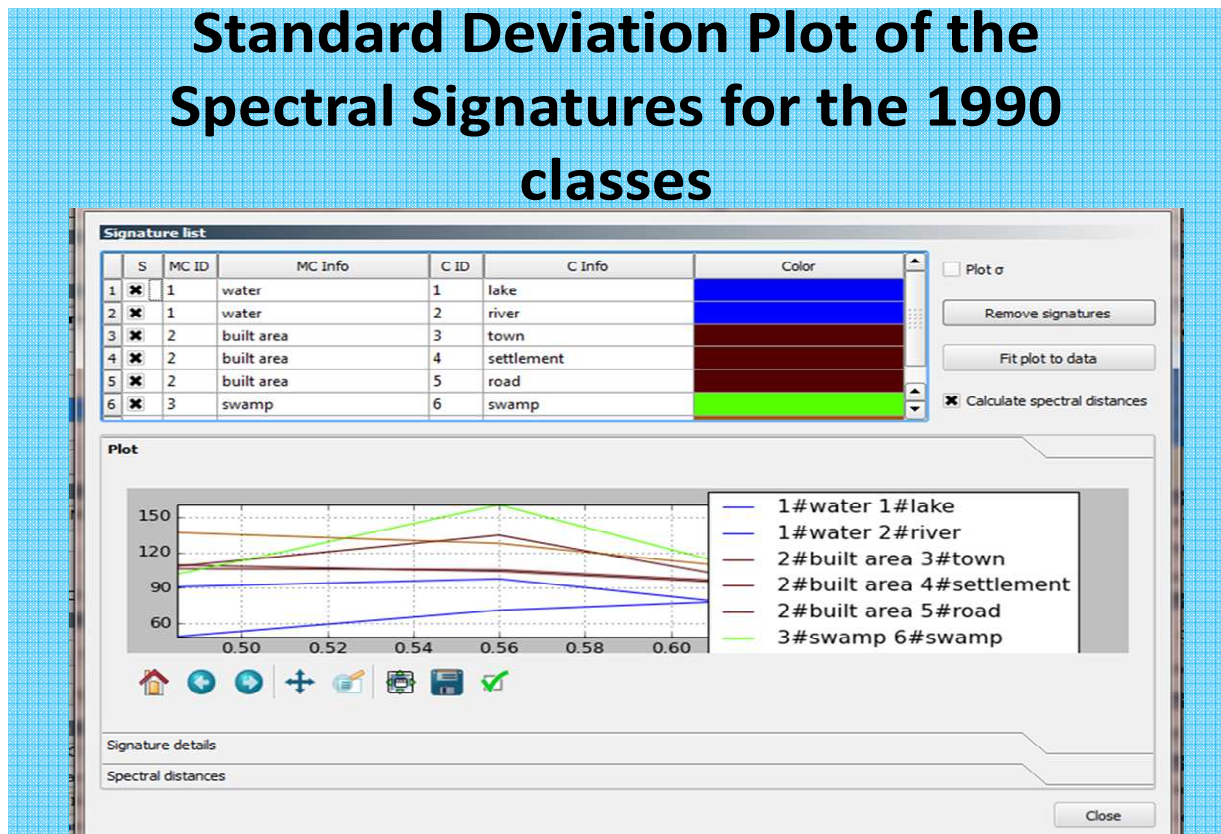
The six classes realised through unsupervised classification were then conglomerated together in four classes depending on the closeness of spectral reflectance as shown in the table below:

Table 4.2   Classes of focus

Macro Class ID (MC ID)	Class ID (C ID)
Water	All surface water
Built Area	Roads and built infrastructure
Swamp	Wetland ecosystem and land use
Bare soil	Cultivated Land, grass thatched structures, bare soil

Fig 4.5: False colour land Sat Imagery depicting surface water and the general hydrological pattern surrounding Dunga Swamp
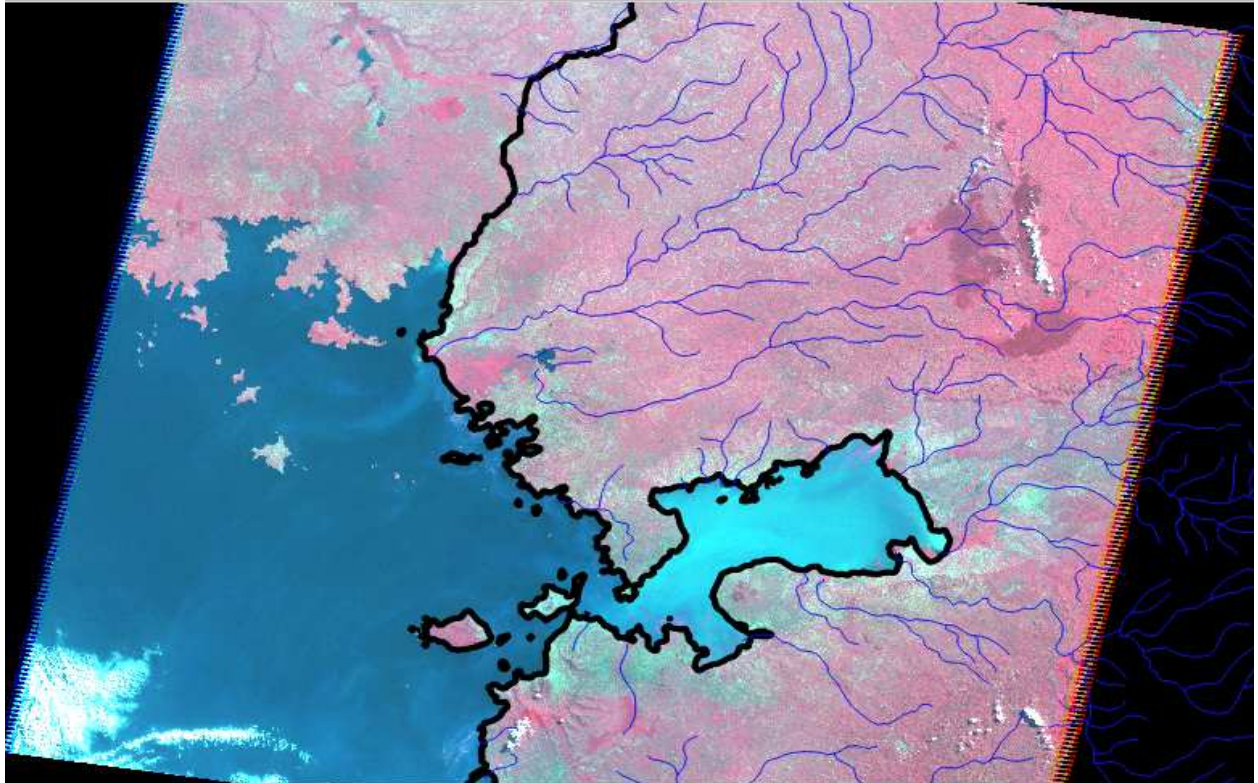
Source: Field Research

4.2.4 Supervised classification of satellite imagery in Raster form

Using Quantum GIS software, all the three imageries underwent supervised classification in raster form (picture form) in accordance with the predetermined classes of focus as shown below.

Fig 4.6: Overall raster output for 1990

Overall Classification Output for 1990

0 - Unclassified
1 - water
2 - built area
3 - swamp
4 - bare soil
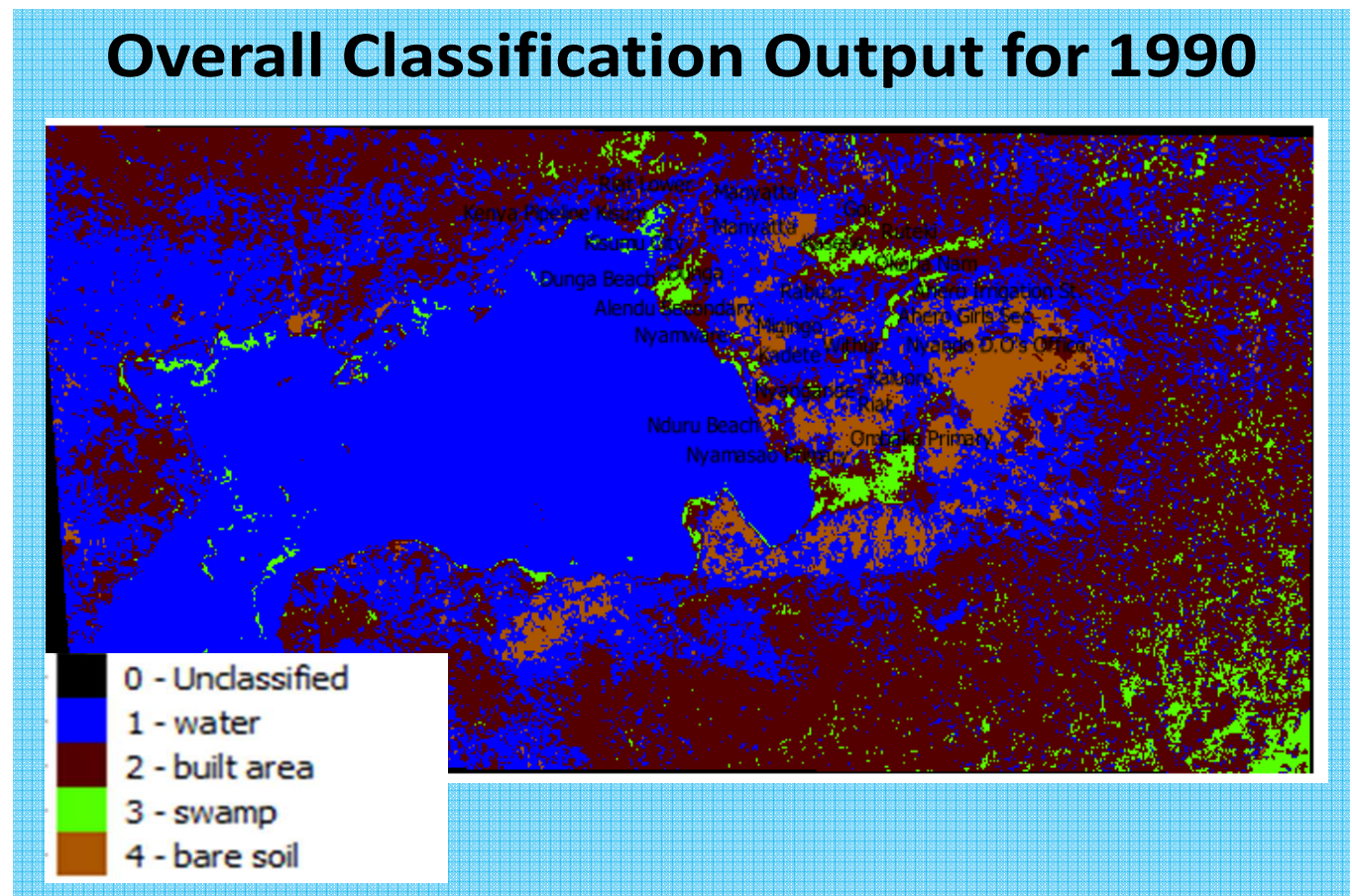
Source: Field Research

Fig 4.7: Raster classification output for 2000

Classified Imagery 2000

0 - Unclassified
1 - water
2 - built area
3 - swamp
4 - bare soil
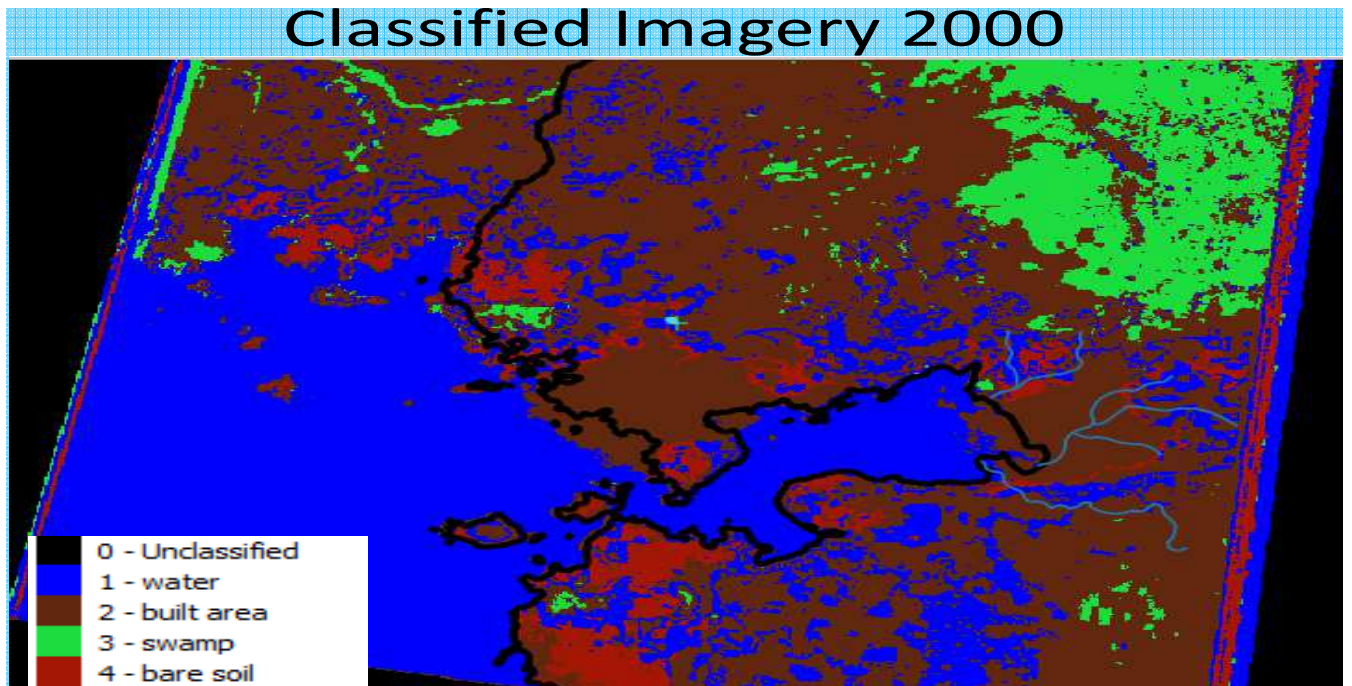
Source: Field Research

 Fig 4.8: Raster classification output for 2011

2011 Classes

0 - Unclassified
1 - water
2 - built area
3 - swamp
4 - farmland
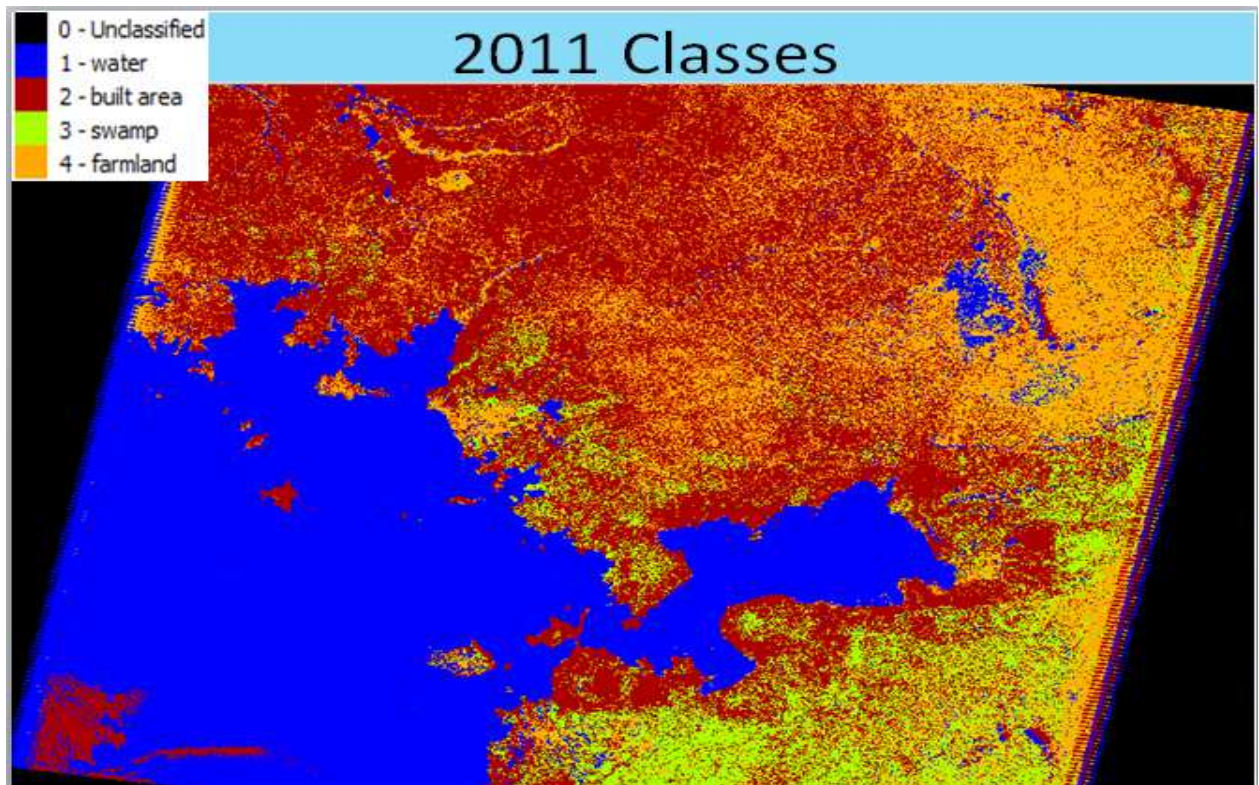
Source: Field Research

From the three classifications, a casual look points out the drastic reduction in swamp area and water as compared to the ever increasing built up area.

4.2.5 Image accuracy assessment

Quantum GIS software was used to determine the level of accuracy from the acquired imageries. The result was full return as shown below.

Fig 4.9: Accuracy assessment reports for Landsat imagery used

Accuracy Assessment Report

- Statistical:

ErrMatrixCode	Reference	Classification	PixelSum
1	1.0	0.0	0
2	1.0	1.0	2660
3	1.0	2.0	0
4	1.0	3.0	0
5	1.0	4.0	2
6	2.0	0.0	0
7	2.0	1.0	0
8	2.0	2.0	32
9	2.0	3.0	0
10	2.0	4.0	0
11	3.0	0.0	0
12	3.0	1.0	0
13	3.0	2.0	0
14	3.0	3.0	24
15	3.0	4.0	0
16	4.0	0.0	0
17	4.0	1.0	0
18	4.0	2.0	0
19	4.0	3.0	0
20	4.0	4.0	33
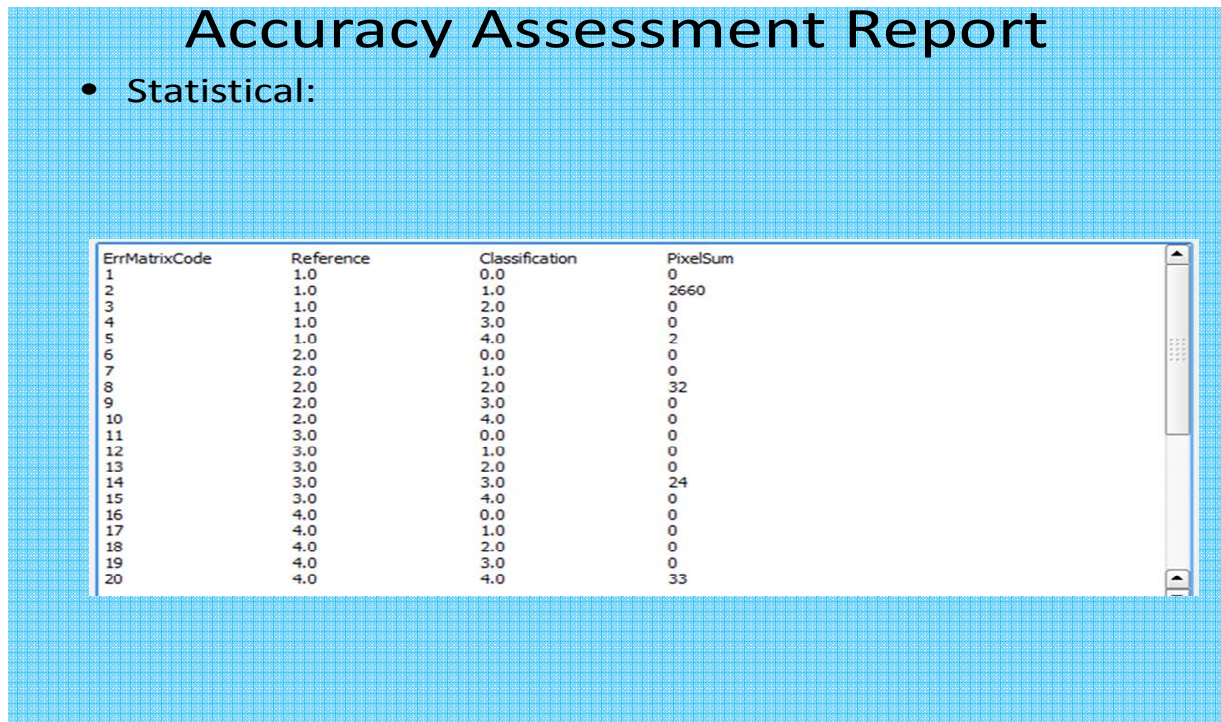
Accuracy Assessment Report

- Statistical (cont'd..):

```
ERROR MATRIX
                   > Reference
V Classification   0.0          1.0          2.0          3.0          4.0
0.0                0            0            0            0            0
1.0                0            2660         0            0            0
2.0                0            0            32           0            0
3.0                0            0            0            24           0
4.0                0            2            0            0            33
Total              0            2662         32           24           33

Overall accuracy [%] = 99.9272991639
Class 0.0 producer accuracy [%] = nan          user accuracy [%] = nan          Kappa hat = nan
Class 1.0 producer accuracy [%] = 99.9248685199                user accuracy [%] = 100.0          Kappa hat = 1.0
Class 2.0 producer accuracy [%] = 100.0        user accuracy [%] = 100.0        Kappa hat = 1.0
Class 3.0 producer accuracy [%] = 100.0        user accuracy [%] = 100.0        Kappa hat = 1.0
Class 4.0 producer accuracy [%] = 100.0        user accuracy [%] = 94.2857142857        Kappa hat = 0.942163355408
Kappa hat classification = 0.988639883054
```

Accuracy Assessment Report

ErrMatrixCode	Reference	Classification	PixelSum
1	0.0	0.0	157614
2	0.0	1.0	0
3	0.0	2.0	0
4	0.0	3.0	0
5	0.0	4.0	0
6	1.0	0.0	0
7	1.0	1.0	240839
8	1.0	2.0	0
9	1.0	3.0	0
10	1.0	4.0	0
11	2.0	0.0	0
12	2.0	1.0	0
13	2.0	2.0	293418
14	2.0	3.0	0
15	2.0	4.0	0
16	3.0	0.0	0
17	3.0	1.0	0
18	3.0	2.0	0
19	3.0	3.0	64908
20	3.0	4.0	0
21	4.0	0.0	0
22	4.0	1.0	0
23	4.0	2.0	0
24	4.0	3.0	0
25	4.0	4.0	36585

Error Matrix Results

```
ERROR MATRIX
                    > Reference
V Classification    0.0                 1.0                 2.0                 3.0                 4.0
0.0                 157614              0                   0                   0                   0
1.0                 0                   240839              0                   0                   0
2.0                 0                   0                   293418              0                   0
3.0                 0                   0                   0                   64908               0
4.0                 0                   0                   0                   0                   36585
Total               157614              240839              293418              64908               36585

Overall accuracy [%] = 100.0
Class 0.0 producer accuracy [%] = 100.0     user accuracy [%] = 100.0       Kappa hat = 1.0
Class 1.0 producer accuracy [%] = 100.0     user accuracy [%] = 100.0       Kappa hat = 1.0
Class 2.0 producer accuracy [%] = 100.0     user accuracy [%] = 100.0       Kappa hat = 1.0
Class 3.0 producer accuracy [%] = 100.0     user accuracy [%] = 100.0       Kappa hat = 1.0
Class 4.0 producer accuracy [%] = 100.0     user accuracy [%] = 100.0       Kappa hat = 1.0
Kappa hat classification = 1.0
```

Source: Field Research

Below is the overall classification report showing the homogeneous pixels percentage and area. Note that the area is in a degree which has to be converted to contemporary measurement yards for ease of analysis.

Fig 4.10: Overall Raster areal classification report

Overall Classification Report

Class	PixelSum	Percentage %	Area [degree^2]
0.0	157614	19.866542974	0.702277865023
1.0	240839	30.3566836912	1.07386721575
2.0	293418	36.98403255	1.30830957906
3.0	64908	8.18136441785	0.289415639658
4.0	36585	4.61137636696	0.163127367611

Source: Field Research

4.2.6 Vectorisation of the satellite imageries

From the raster supervised classification, all the three imageries were vectorised in accordance with clipped area to come up with classes of focus in vector format. The term vector in GIS implies that the images are in form of polygons, lines and dots as opposed to raster format which is in picture form. This was done in order to ease calculation of class area so as to determine the rate of land use change and land cover/ land use detection

Fig 4.11: Vectorised classification of 1990 satellite imagery around Dunga swamp
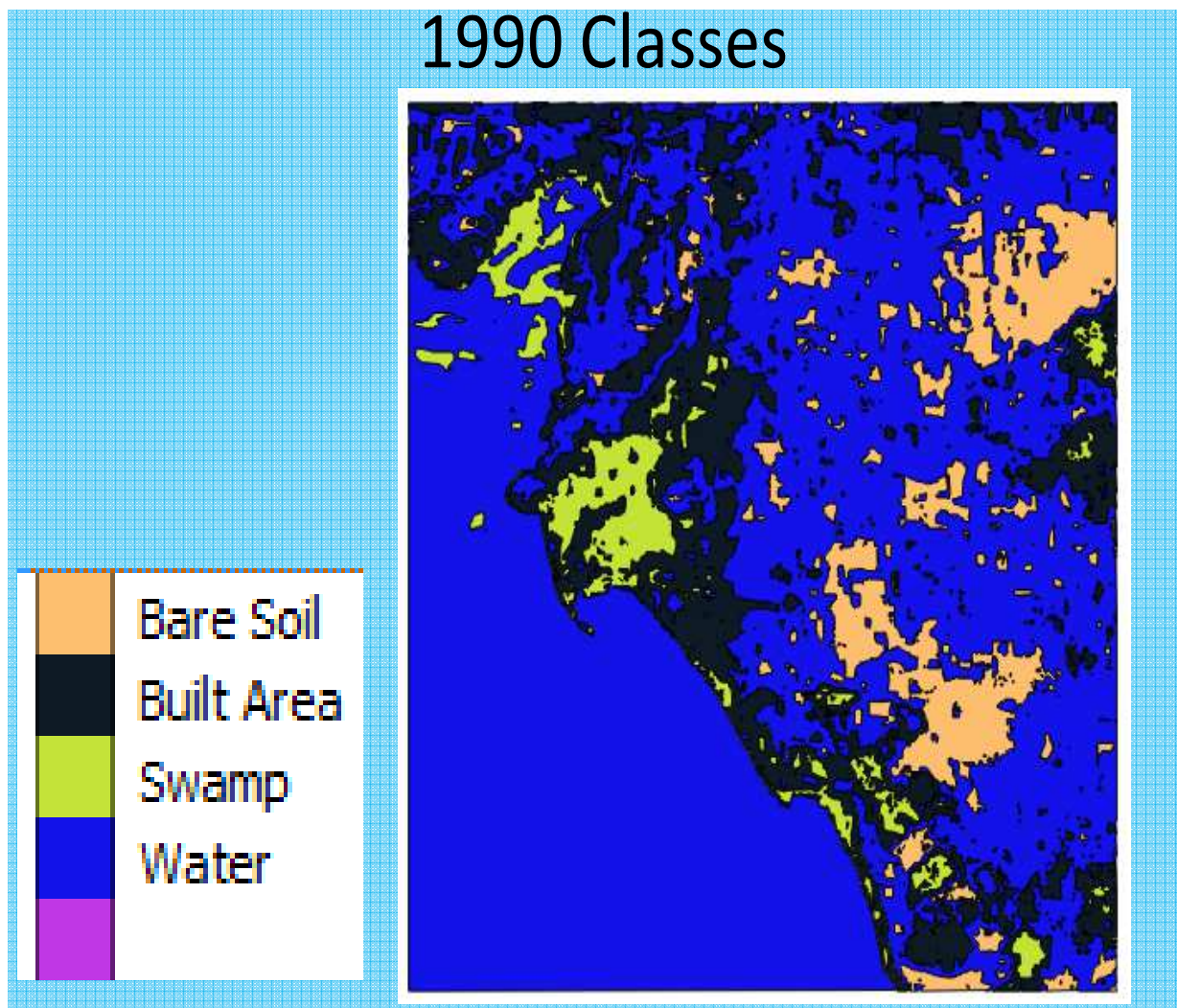
Source: Field Research

It was noted that the swamp was still intact with a predictable perimeter for the 1990 Landsat satellite imagery. Surface water was abundant. Could be the imagery had been captured after heavy rains.

Fig 4.12:   Vectorised classification of 2000 satellite imagery around Dunga swamp.

2000 Classes

Bare Soil
Built Area
Swamp
Water
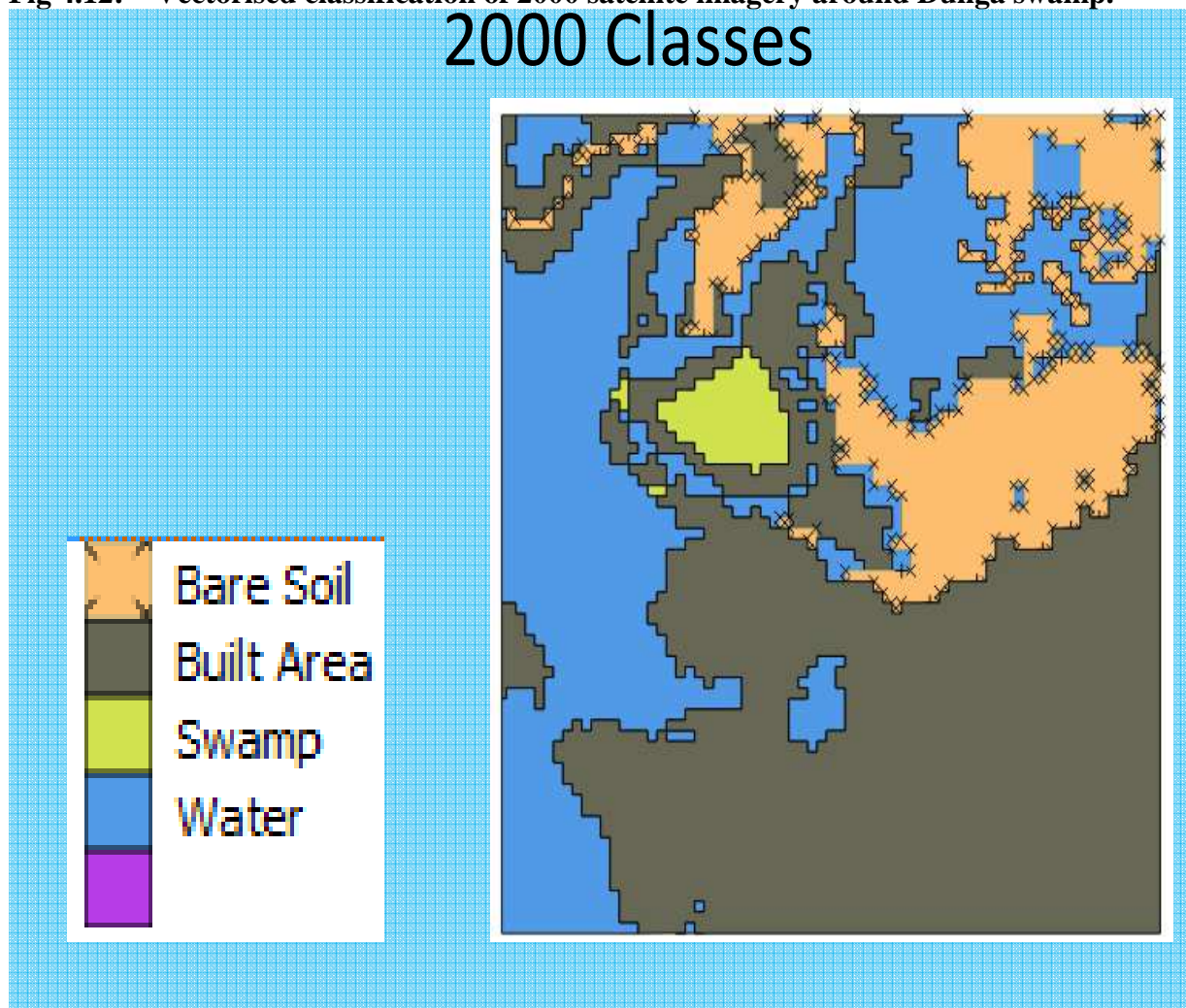
Source: Field Research

From the 2000 imagery, swamp area has greatly reduced as compared to the drastically soared built up area. It can however be noted that the swamp was still solid with a predictable perimeter.

Fig 4.13:   Vectorised classification of 2011 satellite imagery around Dunga swamp.
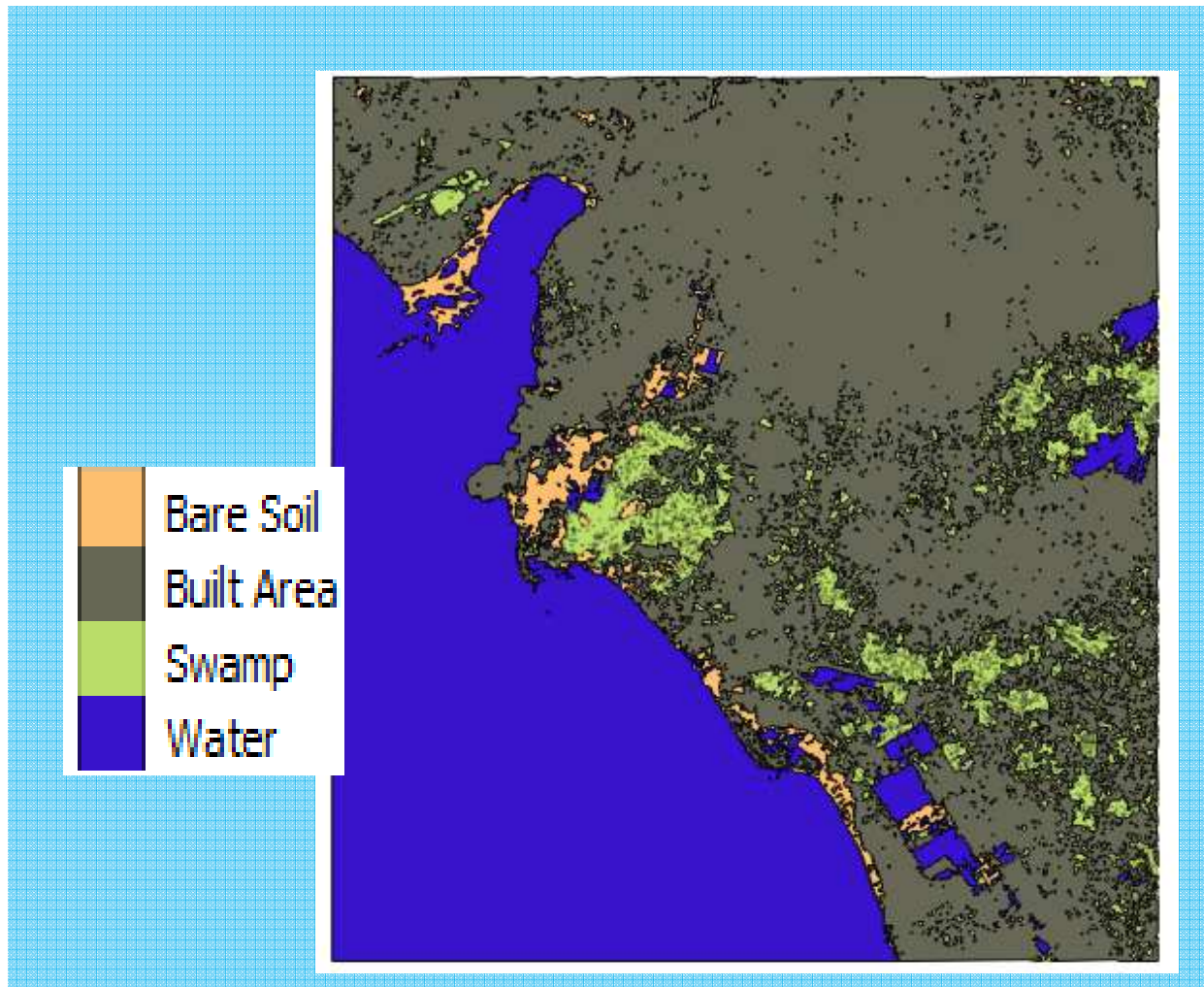
Source: Field Research

The 2011 results depict a reduced fragmented swamp which is heavily encroached by built up area. It is worth noting that the built area at this time was dominating all other land uses and land cover for Dunga and the Kisumu City environs.

4.2.6 Area calculation for the three classified and vectorised satellite Imageries

The vectorised imageries were then opened in Arc View GIS software. The area of each class was then calculated using arcview X tool extension which has capability of calculating area, perimeters and a host of other calculations. The result in table format was again opened in Quantum GIS software and imported to Microsoft Excel and then pasted on word document as follows:

Table 4.3: Class area for 1990 ETM land sat imagery for Dunga Swamp

Attributes of Dunga_1990_classes-utm.shp

Class	Area	Hectares
Bare Soil	27836302.4	2783.63
Built Area	50062140.68	5006.214
Swamp	14007025.38	1400.703
Water	202941406.8	20294.141

Source: Field Research

Table 4.4   Class area for 2000 ETM land sat imagery for Dunga Swamp

Attributes of Dunga_2000_classes-utm.shp

Class	Area	Hectares
Bare Soil	49892747.81	4989.275
Built Area	145162645	14516.265
Swamp	5873486.622	587.349
Water	93916421.97	9391.642

Source: Field Research

Note the increase in built area and the drastic reduction in the wetland area and surface water area for 2000 imagery as compared to 1990 satellite imagery.

Table 4.5 Class areas for 2011 ETM+ land sat imagery for Dunga Swamp

Attributes of Dunga_2011_classes.shp		
Class	Area (Sq. m)	Area (Ha)
Bare Soil	8,765,709.38	876.57
Built Area	160,356,419.30	16,035.64
Swamp	4,932,755.19	493.27
Water	100,312,074.93	10,031.21

Source: Field Research

4.3. *Comparison of combined classes areal change and trends from the Vectorised imageries*

Table 4.6: Percentage change for each class using 1990 as the base year

Class	Area in hectares for the study period			Percentage change using 1990 as base year		
	1990	2000	2011	1990	2000	2011
Built area	5006.214	14516.265	16035.64	100%	290.0%	320.3%
Swamp	1400.703	587.349	493.27	100%	41.9%	35.2%
Bare soil	2783.63	4989.275	876.57	100%	179.2%	31.3%
Water	20294.141	9391.642	10031.21	100%	46.3%	49.4%

Fig 4.14:   Bar Graph trend and change detection comparison of Dunga Swamp Land use from 1990 to 2011
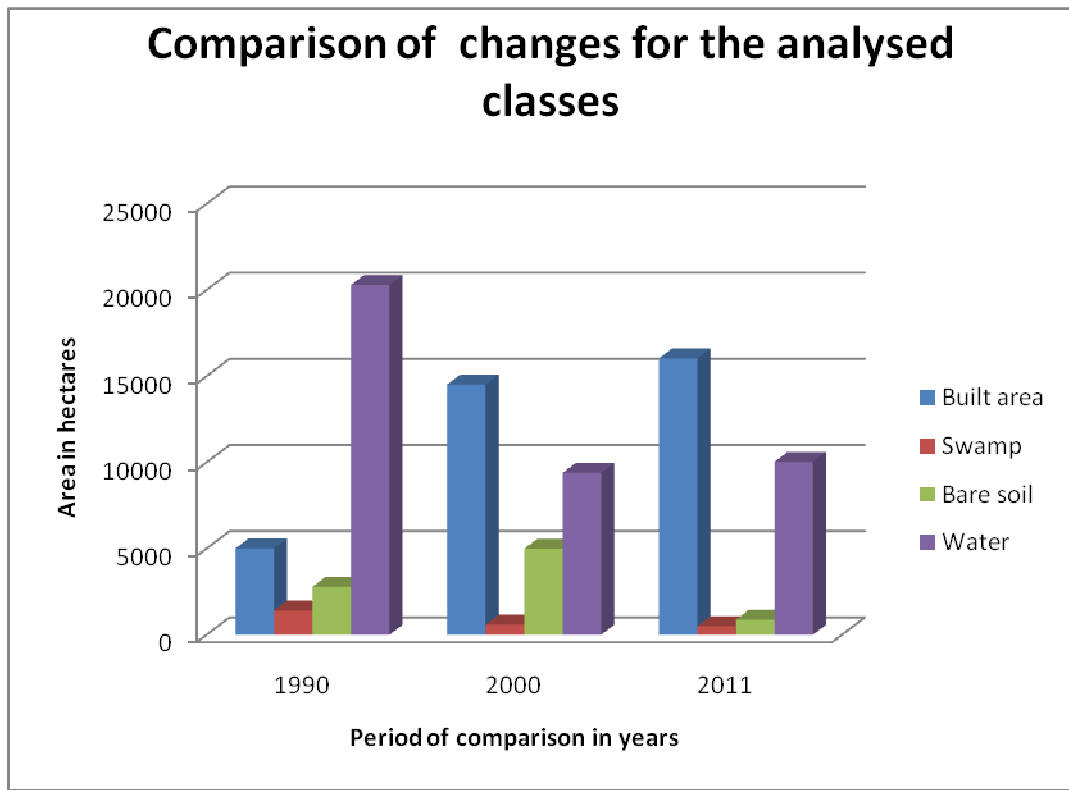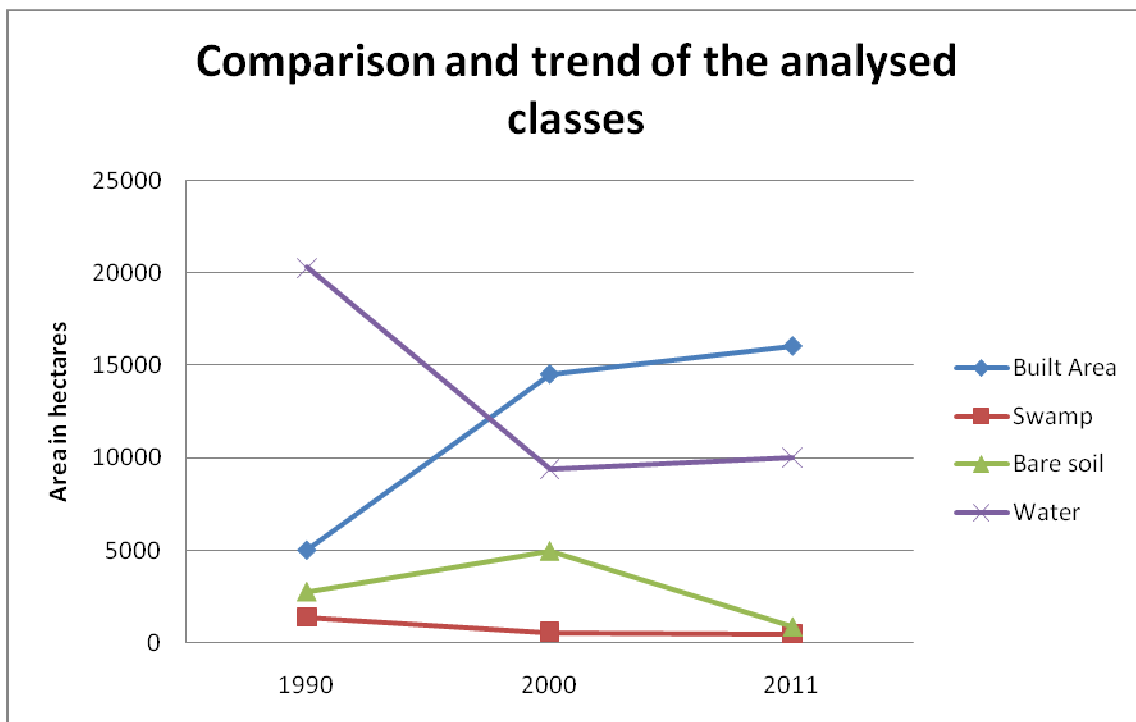

Fig 4.15: line Graph trend and change detection comparison of Dunga Swamp Land use from 1990 to 2011

From the figures in the calculated class areas and as shown in graph and chart above, there is a significant relationship between swamp area, bare land and the built up area. It follows that the swamp area reduced significantly from 1990 to 2000 and at smaller percentage from 2000 to 2011. At the same time the built up area increased tremendously from 1990 to 2000 and then at a steady rate from 2000 to 2011. On the other hand bare soil increased sharply from 1990 to 2000 and then dropped drastically from 2000 to 2011. Surface water area is shown to have been encroached by bare land significantly from 1990 and 2000.

This trend, and as revealed in the vectorised satellite imageries, a larger part of the swamp was converted to built area from 1990 to 2000 and again a significant portion from 2000 to 2011. Bare land is on the fringe of the swamp from 1990 to 2000 and thereby a smaller portion is visible within the swamp in 2011.

In this regard, the built up area has grown at the expense of both the swamp and bare soil from 2000 to 2011.

4.4 Causes of the degradation of Dunga Swamp

Evidence from the analysed satellite imageries and calculated class areas suggest that Dunga swamp had reduced by 64.8 % from 1990 to 2011(refer to table on page 62 on areal change). At the same time, built up area grew by 220.3%.

To augment this, field observations and interiews were conducted from 1st to 7th October 2015. The interviews generated information on land ownership and acquistion, land use changes and approvals as well as human activities around Dunga Swamp. The impacts of human activities, landuse changes and management of the swamp including possible conservation measures were also discussed.

4.4.1 Poor management of Dunga swamp

According to the respondents, the first known human settlements in Dunga swamp was in 1935 by an Indian family who settled in Dunga Village. The family vacated their homes in 1963 and it is not known where they emmigrated to. At this time Kisumu experienced heavy rains which flooded the southern fringe of Dunga swamp thus forcing communities in that part to migrate. Few of these individuals settled at Dunga village right in the swamp (near Dunga beach). The beach was and still is a suitable fishing site. The southern part has remained flooded ever since. It was not clear where the people who opted not to settle in Dunga village migrated to.

An interesting aspect of Dunga village is land ownership. The said migrants of 1963 have since acquired title deeds on a freehold basis. Dunga beach ,which borders the settlement, is managed by the local community even though county government owns the land. All developers on the beach land have to seek permission from the beach management board which is run by the local community.

Fig 4.16:   Photos depicting Dunga beach

Source: Field Research

Field observations depicted scattered construction on the entire swamp. It was also revealed that this constructions were largely on grabbed land. The swamp is prefered due to its proximity to the City and the relatively percieved lack of a specific Dunga Swamp management institution or organisaton.

In accordance with an NGO called Ecofinder that is active in conservation of the swamp ,Dunga is suppposed to be managed by Kenya Wildlife Services Kisumu Impala Sanctuary. Not withstanding this, KWS , Kisumu Impala Sanctuary Officials opined that they only get involved during wildlife-human conflicts that may pose immediate danger to human beings or wildlife as well as in conserving endangered bird species and the Sitatunga Antelop prevalent in the swamp.

It was also revealed that Kisumu County has two departments responsible for physical planning of the County- Kisumu City Planning department under the County government and Kisumu Physical Planning Department under the National government. The Swamp falls under Kisumu City Planning Department's jurisdiction. Kisumu Physical Planning Department reckoned that much of the swamp(especially the northern part)) had been grabbed by key figures and land ownership documents acquired through corruptive means. Therefore the private develoments in the swamp were not approved apart from a few settlements. Infact a sewer disposal unit planned in the swamp had stalled due to this.

NEMA officials were of the opinion that this developments and grabbing were politically motivated.

This lack of a specific institution mandated with managing Dunga Swamp renders it unprotected and vulnerable to encroachment.

Fig 4.17: Construction right in the swamp

Source: Field Research

Fig 4.18:   Land fenced off by a private developer in the swamp

Source: Field Research

4.4.2 Burning of the swamp during dry seasons

There exist different ways by which local communities earn their living. However, the respondents revealed that the swamp and the lake were the major source of livelihood for Dunga community.

Prior to 1963, the swamp was largely undisturbed, from 1963 up to the 1980s, as Kisumu town expanded, the swamp became a conducive ground for fishing, cultivation of maize, sweet potatoes, millet and traditional vegetables. Papyrus harvesting was also carried out. Data from Dunga Pedagogical Centre, run by Ecofinder, pointed out that Kisumu town grew rapidly following the declaration of independence for Kenya in 1963 with the influx of locals into the town. However no population figures could be acquired at that time.

The respondents aknowledged that as the population grew and with depleting fish population in the lake, pressure mounted on the swamp. During dry seasons streams passing through the swamp into the lake are blocked and then the swamp is set on fire to scare mud fish into the streams for easier bumper harvests.

This successive annual burning has adverse effects on the swamp, especially on regeneration of papyrus reeds.

4.4.3 Indiscriminate and excessive harvesting of Papyrus reeds

Closely related to the above point is the indiscriminate, excessive and unsustainable harvesting of papyrus reeds. These reeds are used for thatching, and as grazing grounds for cattle during times of drought. These reeds are also used for making products such as mats

and baskets. It was revealed by the respondents that these papyrus products have a high demand in foreign countries notably the United Kingdom (U.K) thus even more reasons for the overharvesting. All these have continously rendered them unsuitable for ecological functions since the swamp is predominantly Papyrus (Cyperus papyrus).

Fig 4.19: Photos depicting harvested papyrus and the degraded papyrus population
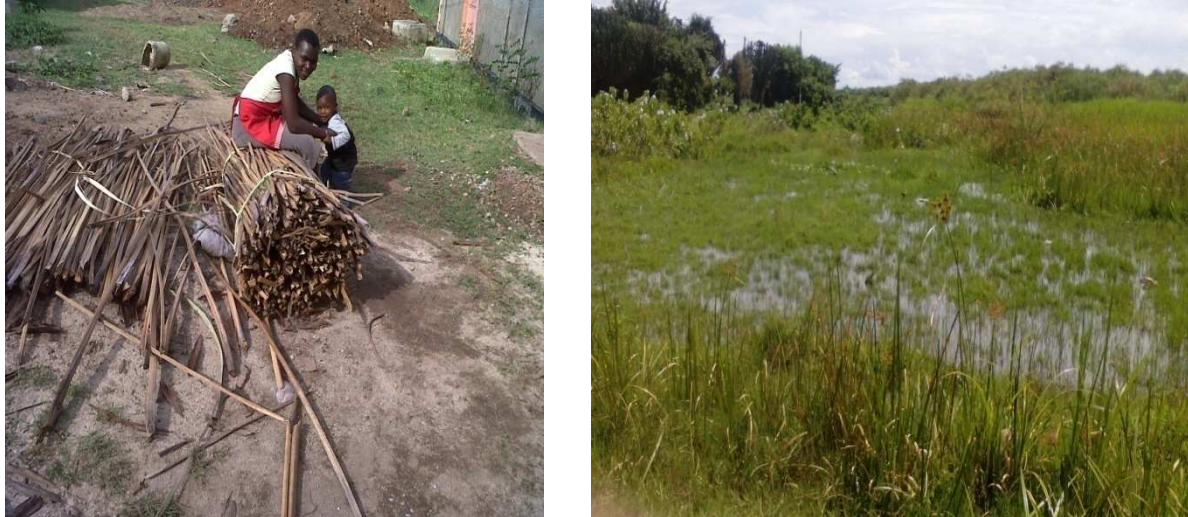
Source: Field Research

4.4.4 Construction and human settlements

Field observations and interview concured with the analysed satellite imageries with indications that there is rapid conversion of Dunga Swamp for housing development. On the same issue there is increasing urban sprawl, moreso on eastern fringes of the swamp with Low-income populations building on the wetland in areas such as Nyamasaria and Nyalenda "A".

4.4.5 Dumping of refuse in the swamp from the City

More so it emerged that the swamp is used as a dumping ground for refuse from the city. An interview with an organisation involved in conservation of Dunga Swamp- Eco Finder- revealed that dumping of refuse and domestic sewerage into the swamp increases the organic loading of the wetland waters. This in turn raises the biochemical oxygen demand (BOD) of the water body, leading to inadequate oxygen supply to support plant and animal life which constitute the Swamp biodiversity. This practice also affects the health of people that depend on the Swamp for livelihood.

Therefore from the findings, the major causes of Dunga swamp degradation were; (1) human settlements, (2) Burning of the swamp (3) Excessive unwanton harvesting of papyrus reeds and (4) Poor management of the swamp

4.5 Framework for sustainable management of Dunga Swamp

Borrowing from the literature reviewed, the key to sustainable management of Dunga swamp, lies in its wise use.

The Elders and organisations interviewed, strongly agreed that the Swamp has created job opportunities for the community as well as a host of other positive benefits. They also were of the view that the major cause of degradation is poor management and human activities and that it is important for the swamp to be conserved.

The two most common methods for protecting wetland functions have been the use of buffers and compensatory mitigation. Buffers are used to maintain existing functions by reducing the impacts of adjacent land uses. When impacts to wetlands are unavoidable, replacement of lost functions has typically been through compensatory mitigation in which other wetlands are created, restored, or enhanced using specific ratios based on area.

4.5.1 Mitigation against effects of human settlements and poor management of the swamp

To curb encroachment and construction in Dunga swamp as well as on the fringes of the swamp, a buffer zone should be created around the swamp. KWS, Kisumu Impala sanctuary should be tasked by the national government with the management of this swamp. By this, the political, corrupt and illigal acquistion of the swamp by private developers who are keen to convert the swamp to real estate and other infrastructure development may be mitigated. Since few individuals own titles, they can be allocated alternative land. However this will require proper planning and consultation with the stakeholders interested in the swamp. The respondents suggested the southern part of the swamp which according to them has no papyrus and supports fewer wetland biodiversity. A historical perspective also indicates this area was good for cultivation but became flooded in 1963. Once the buffer zone has been determined, the swamp should then be fenced off to wade off encroachment and construction. After this, all constructions and buildings in the swamp should be demolished and the areas made good to rehabilitate the remaining 32% of the remaining swamp. Although it will take a long time and the swamp may never be restored to its original condition, this mitigation measure may just boost the biosphere prevalent in Dunga swamp.

Closely related to this, are the the issues of planning and housing development in Kisumu City. Observations indicated that development is not properly planned and zoning is not strictly adhered to except for the low density settlement in Milimani, about 5 kilometres from Dunga Swamp. Given that housing demand is on the rise and that Kisumu City generally

experiences high temperatures, the populace prefers cool areas such as Dunga Swamp for settlement. The solution is to zone it off and restrict it to its original landuse- wetland- by the Kisumu County government which is in charge of development planning in that region. This exercise should be carried out in collaboration with KWS and other stakeholders.

In addition, the County government and National Enviromental management Authority (NEMA) should enforce Environmental Impact Assessiment (EIA) as a Tool for Wetland Management. This will restrict all development in or around the swamp to only those that are of mutual benefit to the Swamp and associated biodiversity.

4.5.2 Mitigation against burning and excessive harvesting of papyrus reeds

The key to sustainable management of wetland ecosystems is availability of relevant information and data. Salum (2007) postulates that wetland management involves valuing local knowledge without ignoring scientific knowledge. Thus using both types of knowledge, a balance can be established where users and conservers can achieve compromises on what should and should not be done for the sake of the wetlands.

Towards this end, there existed traditional methods for protection of the swamp through indigenous management systems in Dunga. The Respondents revealed that before the upsurge of population, most wetlands and their resources were protected and regulated in the past through varied traditional practices. These practices included customary laws and taboos, which determine rights to land and resource use. Sanctions for violation existed. In Dunga this involved controlled harvesting of papyrus and prohibition of farming in the Swamp. For best practices this traditional methods should be revived. In this case the local community should be educated on the importance of wise use as a conservation method and thereby let the village Elders enforce the customary practices that were good for sustainable use of Dunga Swamp.

It also follows that mud fish prevalent in the swamp was never a delicacy to Luo community who prefer Tilapia even up to contemporary times. Infact the price of Tilapia is overly high as compared to other fish species. It is just that the population of Tilapia in the lake has drastically reduced. The interview revealed that organisations involved in conserving Dunga swamp have been advocating for the community to adopt other sources of livelihood that dont entirely depend on the swamp. Fish farming on the shores of lake Victoria was highly advocated for.

Furthermore, the respondents, and in particular, Eco Finder, a local N.G.O involved in conservation of Dunga swamp and associated biodiversity strongly advocated for controlled

harvesting of papyrus reeds. This can be achieved through dividing the swamp into different portions where organised and well regulated harvesting of the papyrus can be carried out by KWS in liaison with the County government and local communities. A service charge can be levied to harvesters to aid in managing the swamp.

4.5.3 Other proposed mitigation measures to degradation of Dunga swamp

According to LVEMP (2014) many Intergrated Wetland Management Plans have targeted wetlands covering a wider area or those that are Ramsar designated. This has left out many other wetlands that play a significant role in there respective local communities. In this case both the National Government through NEMA and KWS, and respective County governments should carry out extensive Environmental Sensibility Mapping for smaller wetlands around Lake Victoria, Dunga swamp being one of them.

Closely related to this is the formulation of a well designed and implemented wetland monitoring and assessment programs. These are critical tools to enhance better management and protection of wetland resources. Such tools should allow for establishment of a baseline in wetland initial extent, condition and function, to detect any change and assess value, as well as to characterize trends over time. This can be achieved through developing a GIS and Remote Sensing based environmental planning tool for wetland management as has been the case in Washington State, United States of America (Washington State, 2005).

Below is a table summarising the proposed sustainable management framework for Dunga swamp:

Table 4.7: Table summarising causes of Dunga Swamp degradation and possible solutions

No.	Threat to the Swamp	Characters	Solution	Level	Responsiblity
1	Poor management	Kisumu City Planning department	Designate KWS, Kisumu Impala Sanctury with the management of the swamp	National	National government KWS
2	Construction in the swamp	Private developers	• Controlled development and Landuse through zoning and physical planning • Enforce EIA as a control tool • Create a buffer for the swamp • Rehabilitate affected areas • Resettlement where possible	Both County and National	County government KWS NEMA
3	Burning of swamp during the dry season	Local community	• Encourage traditional resource use control mechanisms • Resettlement where possible • Rehabilitation • Buffer and	Local Community County government National government	Village Elders and local Administration County government KWS NGOs and

			fencing to allow controlled use		CBOs
4	Unwanton excessive harvesting of papyrus reeds	Local community Residents of Kisumu City	• Encourage traditional resource use control mechanisms • Rehabilitation • Buffer and fencing to allow controlled use	Local Community County government KWS	Village Elders and entire local administration County government KWS NGOs and CBOs
5	Development on the fringes of the swamp	Migrants and local community	• Rehabilitation • Buffer and fencing to allow controlled use • GIS and Remote Sensing maps • Resettlement where necessary • Controlled development	National and County governments	County government Responsible Ministries in National government Local Administration
6	Dumping of wastes and domestic sewer in the swamp	Residents of Kisumu city	• Controlled development • Buffering and fencing of the swamp • Access to designated	National government and County government	KWS NEMA County government

			dumping site		

CHAPTER FIVE

5.0 SUMMARY OF FINDINGS ,CONCLUSION AND RECOMMENDATIONS

5.1 Summary of research findings

5.1.1 Mapping of Dunga swamp

Analysed satellite imageries and calculated class areas revealed that Dunga swamp had shrank by 64.8 % from the base year of study, 1990 to 2011(refer to table on page 62 on areal change). Still the results depicted that the built up area grew by 220.3% from 1990 to 2011 in the swamp.

Further more, the remaining percentage of the swamp is heavily fragmented and not as solid as it was in 1990.

This renders the swamp to be less productive and even perform less functions for instance flood control and water purification. Of direct consequence to the local community is the reduced catches of fish as the breeding habitats are reduced.

5.1.2 Causes of the degradation of Dunga Swamp

Data from observation and field respondents revealed that the major causes of Dunga swamp degradation are; (1) human settlements, (2) Burning of the swamp and (3) Excessive unwanton harvesting of papyrus reeds. Even though dumping of wastes in the swamp also leads to destruction of biodiversity, but the scale is not anywhere near as compared to the three.

From the mapping, the biggest pressure exerted on the swamp stems from human settlements with the built up area nearly replacing the swamp as the major land use.

Usually when much land use is covered by built up area, flash floods increase. Too much flush floods leads to further destruction of the wetland.

Burning of the swamp destroys biodiversity. For Dunga being an extensive papyrus swamp, the successive regeneration of the reeds is therefore hindered thus leading to even further degradation.

The consequences that emanate from burning of the swamp are reinforced by excessive unwanton harvesting of papyrus reeds. This may explain the bare land prevalent in the swamp as revealed by the satellite imageries analysis.

To crown these threats to the very existence of the swamp is the glaring poor management of Dunga swamp. No organisation whether national, County, government Entity or private is responsible in conserving the swamp in its entirety. Even though Path Finder, a local NGO is involved in conservation measures of the swamp, the efforts are only on a volunteer basis and very little is done.

In actual sense, the swamp is exceedingly vulnerable to encroachment and grabbing, the most prominent cause of degradation.

5.1.3 sustainable management framework for Dunga swamp

The framework was formulated to arrest the pressure that arise from human settlements and activities on the swamp.

Based on the internationally accepted wetland conservation measures of buffering and mitigation replacement as well as Ramsar rule of "wise use of wetlands", the solutions were designed such that the responsibilities would be shared by all the responsible stakeholders.

This is due to the fact that, wetlands are common pool resources and thus should be managed by all interested stakeholders including users.

Private ownership of the swamp is strongly discouraged as it is private land owners of the swamp (whether legally or illegaly) that develop the swamp with the sole aim of huge individual profits. This hinders the communal functions, the benefits of which are difficult to replace and may come at a huge cost, such as flood control.

Additional measures were meant to control development around the swamp so that the swamp is preserved to its major land use- a wetland. This would be through zoning, using EIA/EA as a development control tool and general urban planning.

Other mitigation measures are monitoring of changes through modern technologies such as GIS and awareness creation among the stakeholders. Much of the degradation is usually unintentional but emenates from pressures of the ever dwindling resources in urban areas.

5.2 Conclusion

The alternative hypothesis that poor management of human settlements in Kisumu City has lead to degradation of Dunga Swamp is therefore accepted and the null hypothesis that poor management of human settlements in Kisumu City has not lead to degradation of Dunga Swamp is rejected.

As the city grows a lot of strain is put on wetlands, with the major threats to the wetland and the associated biodiversity if proper management measures are not instituted and

implemented. In this study it was revealed the biggest threat to Dunga Swamp is human settlements which leads to long term negative effects that maybe difficult to mitigate if not checked early.

From findings, 64.8% of the swamp had been lost within a period of 31 years. This loss in the swamp area has great repercussions on the associated biodiversity especially the rare Sitatunga and Gonoleck bird which is found only in Dunga swamp, as well as other benefits of wetlands outlined in chapter two of this study.

To this end, natural Wetlands ecosystems are valuable assets in our nation. In urban areas, the wetlands are beneficial especially to the urban poor, most of who rely directly on them for survival. To manage them effectively and efficiently requires the understanding of the dynamics of human and environmental parameters at play. World over, individual profit as opposed to communal benefit is the main cause of wetland destruction.

To curb this, government, NGOs, local communities and other stakeholders should and must enforce policies that emphasize collective or social value rather than individual benefits, institute proper development control and urban management measures that must be fully implemented. The traditional conservation methods were hitherto prevalent should be embraced while efforts to prevent further degradation are put in place.

5.3 Recommendations

Since the swamp had reduced by 64.8%, much of the swamp is already lost while the remainder is heavily fragmented and still facing pressure from human settlements.

Measurements must therefore be geared towards conserving this remaining 35% while efforts to grow it to a larger percentage should be emphasized. This responsibility falls heavily on KWS and the County government.

NEMA should ensure that any development, alteration or papyrus harvesting in the swamp is subjected to approved standard procedures that may include Environmental Impact Assessment (EIA), Cost Benefit Analysis (CBA), and adequate public participation.

Creation of public awareness on values, roles and importance of wetland conservation and management should be emphasied. Contribution of NGOs and local communities is crucial in the management of this swamp. Involving the public in wetland management ensures that they value the importance, benefits and functions of wetlands.

With revelation that the built up area is rapidly taking over as the major land use in the swamp, the study recommends that further construction in the swamp should be prohibited

the while other buildings decommissioned to pave way for mitigative regeneration of the swamp. NEMA and County government of Kisumu should implement this.

Controlled harvesting of papyrus reeds should be instituted and fully implemented. At the same time burning of the swamp during any season should be prohibited.

All stakeholders should ensure that effective wetland management strategies are dependent on the involvement of local communities whose livelihood are interlinked with the wetlands and whose daily activities directly affect the wetland ecosystem.

Protection of these fragile ecosystems is thus to be for the people and not against them.

5.3.1 Further research and improvement

The study findings provided an avenue of identifying areas of further research based on the challenges and limitations experienced during the study. I would therefore recommend the following areas:

- Studies on the Economic Invisibility of Nature,

- Studies on the Value of lost Ecosystems

- Studies on the Economic valuation of Dunga Swamp in Kisumu city.

- Studies on Effectiveness of urbanisation as an environmental management tool

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APPENDICES

INTERVIEW ON SUSTAINABLE MANAGEMENT OF NATURAL WETLANDS IN URBAN AREAS: CASE OF DUNGA, KISUMU

SECTION A: PERSONAL DETAILS

1. Name of interviewee...
2. Place of birth...
3. Gender ....
    a. Male
    b. Female
4. Age bracket in years...
    a. 18- 25
    b. 26-35
    c. 36-45
    d. Over 46
5. Marital status.......................single/married/ widowed
6. Do you have children............yes/no
7. If yes above, how many ....
8. Are you indigenous to this area?.......................Yes/No
9. If not indigenous what was the reason for immigrating to this area
    a. Agriculture
    b. Livestock keeping
    c. Fishing
    d. Tourism
    e. Employment
    f. Small business entrepreneur
    g. Others (specify)
10. For how long (years) have you lived in Dunga
    a. 0-10 years
    b. 11-20 years

    c.   2030 years

    d.   30- 40 years

    e.   50 and above

11. What is your highest level of education?.............................

    a) University

    b) College

    c) Secondary

    d) Primary

12. What is your current occupation?........................

    a) Government Employed

    b) Self employed

    c) Others

SECTION B: LAND OWNERSHIP AND ACQUISTION

1. Do you own a piece of land in Dunga.....................yes/No

2. If yes how did acquire it..............
    a. Inherited
    b. Given by the Government
    c. Bought
    d. Other

3. Do you land ownership document for the land you own--------yes /No

4. If yes, what kind of documentation.............................

    a. Title deed

    b. Communal

    c. Written Agreement

    d. Others

5. In your own knowledge, how do you describe land tenure in Dunga-----------

    a. Communal land

    b. private land ownership

    c. Government land/ squatting

    d. Others

6. If private/ individual ownership, is it leasehold or freehold ....

SECTION C: QUESTION ON LANDUSE CHANGES AND APPROVALS

1. In your own opinion, what was the traditional landuse around Dunga Swamp?

   Papyrus harvesting---

   Fishing---

   Grazing grounds---

   Agriculture---

   Human settlements--

   Others (specify)---

2. Do you think this landuse was compatible with the wetland? Yes/ No.

   ----

3. If no what was its effect on this wetland

   ----

4. Has there been any landuse changes in regard to question 1 above for the past 30 years? Yes/ No

   ----

5. If yes what changes--

6. Does the said changes effect Dunga Swamp? Yes/ No-------------------------------

7. If yes what effects---

8. Are the developments in Dunga approved..............Yes/No

9. If yes, who grants the approval-------------------------

   1. County government
   2. National government
   3. Others(specify(

SECTION D: QUESTION ON HUMAN ACTIVITIES

1. As an individual, do you engage in any activity on the wetland?

   a) Yes

   b) No

2. In your own observation, are there human activities being carried out in wetland?

   a) Yes

   b) No

i.   If yes in (6) above, briefly state them.

_____
_____
_____
_____
_____

ii. If no, in (6) above, why?

_____
_____

3. How have the activities mentioned above benefited you as an individual?
   a) Food provision
   b) Income generation
   c) Shelter materials
   d) other
      (specify)_____

4. How have the activities mentioned above benefited the community living around wetlands?
   a) Food provision
   b) Income generation
   c) Shelter provision
   d) Others   (specify)

   _____

5. In your own understanding, list the most beneficial and the most destructive human activity to the wetlands.

   Most beneficial
   _____
   Most destructive

SECTION E: QUESTIONS ON THE EFFECTS OF HUMAN ACTIVITIES AND LANDUSE CHANGES ON WETLANDS

1. To what level do you agree with the following statements

	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
The size of wetland has been affected by human activities					
The size of wetland has been affected by surrounding traditional land uses					
The size of wetland has been affected by current land uses					

	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
The wetland has created job opportunities					
The Wetland act as a source of income					
There are many others positive benefits from the wetland					
Human activities are the major cause of wetland destruction					
Conservation of Dunga Swamp is important					

SECTION F: CONSERVATION STRATEGIES

1. Are the developments around Dunga Swamp approved..............Yes/No
2. If yes, who grants the approvals
   a. National Government
   b. County Government
   c. Others (specify)
3. Does the community participate in any conservation measures of wetland?
4. Is there any organisation in Dunga involved in the wetland conservation
5. If yes which one.........
6. What kind of conservation measures......................

   Mitigation measures
   Buffering
   Others (specify)
7. Are there any efforts by the either the National or County governments in Conservation of the wetland-------------yes/No.
8. If yes which ones
   a. Mitigation
   b. Buffering
   c. Others (specify)
9. If yes for both questions 5 and 8, is the community in Dunga involved.............yes/No
10. If Yes, how
    a. Use of Barazas
    b. Use of Local Administration
    c. Use of regulations
    d. Nyumba Kumi
    e. Others (specify)
11. What strategies would you suggest to help enhance conservation of this wetland?_____

    _____

    _____

This is the end of the questionnaire. Thank you for your time.

Landsat Bands combination and Electromagnetic Spectrum wavelength

Landsat 8	Bands	Wavelength (micrometers)	Resolution (meters)
Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	Band 1 - Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
	Band 2 - Blue	0.452 - 0.512	30
	Band 3 - Green	0.533 - 0.590	30
	Band 4 - Red	0.636 - 0.673	30
	Band 5 - Near Infrared (NIR)	0.851 - 0.879	30
	Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	30
	Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	30
	Band 8 - Panchromatic	0.503 - 0.676	15
	Band 9 - Cirrus	1.363 - 1.384	30
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)

* TIRS bands are acquired at 100 meter resolution, but are resampled to 30 meter in delivered data product.