INFLUENCE OF ANTHROPOGENIC ACTIVITIES ON NYANGONGO WETLAND IN NYARIBARI CHACHE SUB-COUNTY, KISII COUNTY-KENYA

BY

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DECLARATION

Declaration by Student

This thesis is my original work and has not been submitted for any academic award in any institution; and shall not be reproduced in part or full, or in any format without prior written permission from the author and/or University of Eldoret.

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This thesis has been submitted with our approval as the university supervisors.

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DEDICATION

To My family, who have constantly encouraged, motivated, supported, and strengthened me, are the ones to whom I vehemently dedicate this work.

ABSTRACT

Wetlands have a variety of crucial functions, such as flood mitigation, groundwater recharge, climate regulation, erosion prevention, and the provision of water for human use and wildlife habitats. The Nyangongo Wetland, which spans 825 hectares in Kisii County, Kenya, is a vital source of sustenance for communities living in the Lake Victoria Basin. However, due to land consolidation, the conferment of individual land rights, and population pressures, some members of the community have lost access to land, resulting in encroachment on sensitive areas like wetlands. This phenomenon can be attributed to a combination of colonial land practices and traditional customs, which have led to the encroachment of traditionally protected areas like sacred forests and communal wetlands. The study was based on the tragedy of the commons theory, which discusses open access to environmental resources, and aimed to evaluate the impact of human activities on the Nyangongo wetland over the past 37 years. To achieve this, a mixed-method approach was utilized, combining Remote Sensing and GIS-based analysis with citizen science methodology. The research findings indicate that the wetland has been adversely affected due to human-induced modifications such as water pollution, which has led to limited access to clean water and a reduction in arable land. The research utilized image analysis to determine that the size of the wetland area of which in 1984 was 72.85 hectares, but by 2021 had significantly reduced to 17.37 hectares, indicating a significant decrease of 76%. Over the same period, the vegetation area decreased from 609.07 hectares (73.8%) to 148.86 hectares (18%), while the farmland area increased from 135.65 hectares (16.4%) to 473.85 hectares (57.4%). The built-up area, which was previously only 7.65 hectares (0.9%) in 1984, expanded to 185.14 hectares (22.4%) in 2021 due to population pressure. Loss of biodiversity was identified as the most significant negative environmental impact of the Nyangongo wetland, as agriculture expansion and settlement have resulted in the loss of over 460.21 hectares of vegetation. The study's results suggest that to protect the Nyangongo wetland's resources, the County and National governments should declare it an Environmentally Sensitive Area. Furthermore, they should devise intervention strategies to regulate, restore, and relocate any land uses that are harmful to the wetland. In addition, promoting responsible use of the wetland is essential to ensure its preservation for future generations.

Key Words; Wetland, human activities, Restoration, spatio-temporal

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ACRONYMS AND ABBREVIATIONS

ERDAS	Earth Resource Data Analysis Software
ETM	Enhanced Thematic Mapper
GIS	Geographic Information System
GOK	Government of Kenya
GPS	Global Positioning System
ICDP	Integrated County Development Plan
LADA	Land Degradation Assessment
LANDSAT	Land Resource Satellite
NEMA	National Environment Management Authority
SPSS	Statistical Package for Social Scientists
WRMA	Water Resources Management Authority
WRUA	Water Resource Users Association
UNEP	United Nations Environmental Program
UNESCO	United Nations Education, Scientific and Cultural Organization
MEA	Multilateral Environmental Agreements
WFF	Wetland Future Fund
FAO	Food and Agricultural Organization
TEEB	The Economics of Ecosystems and Biodiversity
LULCC	Land Use Land Cove Classification

OPERATIONAL DEFINITION OF TERMS

Land use: Activities performed by humans that alter or transform the existing land cover from one form to another.

Land cover: This pertains to the distinct types of vegetation and surface cover that define a specific region.

Land use change/Land cover change: Refers to the numerical alteration in land cover

or land use categories.

Landsat: This is a collection of satellites that utilize remote sensing technology to observe the Earth and capture pictures of the world's terrain.

Stratified random sampling: Researcher first divide a population into smaller strata based on shared characteristics then randomly select members among these groups to form the final sample.

Ecosystem: Is a product of a complex interplay between communities of plants, animals, microorganisms, and the non-living environment.

Ecosystem resilience: This term describes an ecosystem's capacity to handle and adapt to disruptions and recover from them. Ecosystems with high resilience can more swiftly respond to natural disturbances like pest outbreaks, flooding, and fires than those with low resilience. Ecosystems that are degraded typically possess lower resilience, making them less capable of recovering from disturbances.

Biodiversity: A diverse array of living organisms that can be found in both aquatic and terrestrial environments.

Ecological restoration: This is the process of an ecosystem returning to a state of structural and functional similarity to its condition before it was damaged.

Environmental conservation: The act of avoiding the depletion, spoilage, impairment, or ruin of the natural surroundings.

Environmental management: Environmental governance involves managing and regulating the condition and welfare of the environment through decision-making and control measures.

Threat: The term describes any element that presently or could potentially have a harmful impact on the components or operations of a wetland. In the context of Nyangongo wetland, examples of such threats are agricultural practices, human habitation, institutional activities, and the introduction of non-native species.

Values: These are the internal standards or beliefs that influence the conduct of an individual or group, and shape their attitudes towards the natural environment and their role in it.

Carbon stocks: To put it differently, carbon stocks are the pools of carbon that exist in living organisms and soils. They are mainly present in various ecosystems, including tropical forests, wetlands, peat lands, sea grass beds, and mangroves.

Restoration: Restoration refers to the intentional effort of assisting the recovery of an ecosystem that has undergone damage, degradation, or destruction. The aim is to preserve the ecosystem's resilience and safeguard biodiversity.

Rehabilitation: Restoration of fundamental ecological processes in a wetland in order to enhance its well-being and ability to provide important ecological services.

Management strategy: This refers to a series of measures or steps that will be implemented to accomplish objectives related to a specific aspect or function of a wetland.

Producer's Accuracy: The term refers to a metric that quantifies the accuracy of classifying a reference pixel. It calculates the omission error by identifying reference pixels that are misclassified and excluded from their correct category.

User's Accuracy: This metric measures the commission error, which occurs when image pixels are classified incorrectly and assigned to a reference class other than the correct one.

Overall Accuracy: This evaluation method is based on the proportion of correctly classified pixels for each image class. It provides a measure of the overall accuracy of the image without considering the specific categories.

Kappa coefficient: This is a metric that quantifies the level of agreement or accuracy between a classification map generated by a model and the reference data used to train and validate the model.

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

Wetlands encompass areas that are periodically or permanently flooded with water and are classified as marshes, fens, fringes of lakes, rivers, flood basins, estuarine deltas, ponds, river fields, and marine water areas according to the Ramsar Convention of 1971 (Bridgewater & Kim, 2021). These water sources can be either static or flowing, fresh, brackish, or salt, or not exceeding a depth of 6 meters at low tide. Wetlands are acknowledged as the most diverse and productive ecosystems globally.

According to Ramsar, there are currently over 2,400 recognized sites across the world, occupying over 2.5 million square hectares of land. Ramsar's objective is to contribute to sustainable development on a global scale by conserving and making judicious use of wetlands through local, regional, national, and international endeavors (Panigrahi, 2007).

With a variety of biological and socioeconomic purposes, wetlands continue to be important to society. Ecological and regulatory services include preventing erosion, reducing the severity of severe flows, creating sediment traps, altering the climate, forming soil, maintaining nearby areas' water tables, and serving as hubs for biodiversity and wildlife habitat. Food, medications, water supplies, fisheries, dry season grazing for cattle, nutrient and toxin retention, tourism, and other socioeconomic or provisioning services are examples. Crafter et al. (1992) highlights that wetlands have significant ecological as well as aesthetic, recreational, and spiritual value. Freshwater ecosystems host over 40% of the world's 20,000 fish species. Wetlands are crucial genetic stores for plants, some of which are precious resources for human well-being. Wetlands, such as those used for growing rice, are a vital source of food for over half of the world's population. Despite being viewed as barren land throughout history, wetlands remain some of the most pristine and untouched natural environments on the planet.

Wetlands are under severe threat on a global scale in part due to increase in the demand on land brought on by growing populations throughout the world. Traditional resource-use systems are being disrupted by demographic pressure that is causing a rise in the demand for agricultural land. Conflict arises between wetland users nowadays as a result of wetlands being a desirable resource for a variety of economic and social activities (Mitchell, 2013).

There is growing global concern about the state of the environment, particularly regarding wetlands' ecological importance and the increasing risks to environmental conservation. Rebelo et al, (2010) have outlined various national and international initiatives aimed at protecting wetlands from human activities. The Rio de Janeiro Conference of 1992 (Jiang & Li, 2022), and the Copenhagen climatic Meeting of 2009, (Bodansky, 2010, Rebelo et al., 2010) all emphasized the dangers that regional and global climate change pose to the land resources required for human survival. Wetland loss remains a pressing issue, particularly in developing countries, despite growing awareness of their importance. This is mainly because many developing nations depend heavily on wetland resources, particularly biological ones, with these resources mainly located in underdeveloped rural areas where resource exploitation is often the only source of income (Gärdenfors & Stattersfield, 1996). Due to a lack of understanding about the value of wetlands and the low priority given to them in decision-making, wetlands have been continually destroyed or modified, resulting in an unrecognized social cost. Wetlands are facing a threat due to human activities, and over 50% of inland wetlands around the world have disappeared. Agricultural practices are responsible for a significant portion of this loss, with estimates suggesting that agriculture is the cause of the disappearance of 56-65% of wetlands in North America and Europe, 27% in Asia, 6% in South America, and 2% in Africa (Ngodhe et al, 2016). When wetlands are able to handle stressors and shocks and recover from them so they can retain or develop their capacities in the future, they are said to be sustainable.

1.1.1 Wetlands in Kenya

Kenya has wetland ecosystems that make up 3-4%, or 14,000 km2, of its total land area (Raburu et al, 2012). Kenya has a rich cultural history due to its diverse topography and climate. There are six types of wetlands in Kenya: riverine, lacustrine, palustrine, estuarine, marine, and some artificial wetlands. The inland wetlands in Kenya cover a vast area of 2,641,690 hectares, which is much larger than the 96,100 ha of marine and coastal wetlands. However, due to the fast rate of degradation of wetlands and watersheds, the total wetland area is thought to have decreased to below 2%, (Duvail et al, 2012).

In 1990, Kenya's wetlands received their first international attention as an ecosystem with the ratification of the Ramsar convention. The Ramsar convention designated the 1,045 sq km area of Lakes Nakuru, Naivasha, Bogoria, and Baringo as wetlands of international importance in 2009. Lake Elmentaita and Nakuru were also added to the UNESCO World Heritage List during the 35th session in Paris, France in 2011. A ministerial declaration by the Kenyan government in 2013 recognized wetlands as essential to the country's socioeconomic development.

Wamiti et al., (2020) noted that wetlands in Kenya are threatened by a range of factors, including human activities and natural events. The majority of wetlands (around 80%) are located on privately or communally owned land and lack effective conservation measures. Human practices, such as unsustainable agriculture, overgrazing, fires, urbanization, industrial use, and infrastructure development, pose the most significant danger to wetlands, leading to siltation, drying-up, and pollution. While natural factors such as drought and aridity may also have an impact on wetlands (Chipps et al., 2006) these are beyond human control.

According to a research conducted by Kipngeno et al, (2020) in Kenya, excessive use of water pumps and encroachment on river banks for agriculture were identified as the primary human activities causing a conflict between the community and natural resources. The study concluded that these activities have resulted in environmental degradation and the participants agreed that the wetland could become extinct in the near future.

Wetlands, although often viewed as unproductive land, are crucial in providing various ecological and socio-economic benefits to rural communities living near them. Despite this importance, the prevailing notion of wetlands as unproductive land has resulted in their continuous degradation and loss due to several human activities, including conversion to farmland, settlement areas, waste disposal areas, industrial development, and overexploitation of their biodiversity. This degradation is particularly severe in small wetlands like Nyangongo in communal lands, where rural communities rely heavily on wetlands. These communities face challenges such as poverty, food insecurity, and poor living standards, making it difficult to manage small wetlands sustainably. The situation is expected to worsen with population growth, leading to a reduction in wetland ecosystems' size and potentially causing permanent destruction.

1.2 Research Problem

The practical importance of wetland is to sustain a variety of benefits such as water provision, food supply, fuel wood, grazing pastures, flood control, medicinal harvesting, recharge of aquifers and climate regulation among others. Despite the acknowledgment of the importance of wetlands at a global and local level, these ecosystems have persistently been depleted and excessively utilized.

The primary factor behind the over- exploitation of this resource is because the wetland has not been gazetted by the county government to clearly demarcate its boundaries to enhance its conservation. This has led to residents encroaching on Nyangongo wetland, a common resource due to its easy access for settlement, crop farming and other socio-economic activities.

The wetland, classified as trust land, is subject to the jurisdiction of the national land commission, which requires ownership to be governed by the Trust Land Act. Under this law, all rural land that is not government-owned or privately owned is vested in the county government to hold in trust for local residents.

The colonial land tenure practices had overridden the traditional customary practices resulting to an increase in trespassing on lands that were traditionally off-limits, including forest lands that were considered sacred and wetlands that were preserved for communal resources like thatching materials, white clay used for house decorations, and grazing areas for livestock. The consolidation of land and the establishment of individual land ownership rights, along with the rapid population growth in the area, have reduced land access for some members of the community, resulting in encroachment on sensitive areas such as wetlands.

The local community have illegally allocated the wetland to themselves to perpetuate their immediate survival needs such as intensification of agricultural activities to support the high demand for both local and international markets, brick making as the major construction material in the area and growth of Eucalyptus trees for supply to tea processing factories due to their fast maturity. This has contradicted the long-term conservation strategies. It is clear that the integrity of this wetland has been negatively affected by human activities. This is majorly attributed to stakeholder’s failure to observe and implement legislation for protection of these wetlands due to inadequate financial support to enhance monitoring and regulating human activities in wetlands to ensure the continuous provision of ecosystem services, political influence and resistance from local communities due to lack of awareness on wetland value, conservation and restoration. The degradation of the wetland has impeded the natural regeneration of its resources, and the local community has been unable to fully benefit from them. If this degradation persists, the rehabilitation of Nyangongo wetland would take a considerable amount of time, as many of its biodiversity and services would be lost. There is urgent need therefore for this research to examine the effects resulting from human activities both on-site and off-site so as to recommend viable strategies.

1.3 Overall Objective

The primary aim of this study was to assess the impact of human actions on Nyangongo wetland for the past 37 years (1984 to 2021).

1.3.1 Specific Objectives

This study has three specific objectives;

1) To examine the spatial- temporal change of land use and land cover in Nyangongo wetland
2) To find out the human activities carried out on Nyangongo wetland
3) To find out the causes influencing human encroachment on Nyangongo wetland.

1.3.2 Research Questions

The research study has four research questions;

1) What are spatial and temporal changes of land use practices on Nyangongo wetland?
2) What are the various human activities carried out on Nyangongo wetland?
3) What are some of the causes of encroachment on Nyangongo wetland?
4) Are the local community members aware of wetland conservation measures?

1.4 Significance of the Study

The ongoing reduction of wetlands is a matter of global concern due to the decline in their ability to provide ecosystem services and goods. Human activities pose a risk to wetland biodiversity, leading to erosion and loss of resources, as highlighted in the 2005 Millennium Ecosystem Assessment Report.

The depletion of natural resources is commonly linked to population growth and the need to expand agricultural land to satisfy the rising demand for food. Nevertheless, there has been a lack of adequate policy implementation to achieve a balance between conserving and utilizing these resources. As a result, it is necessary for the government to commit to using national planning tools and county government guidelines to regulate open access to wetlands, which can lead to their undesirable destruction. It is crucial to evaluate the potential of the wetland and its ability to support local livelihoods to develop recommendations that prioritize sustainable use of resources while maintaining a delicate balance between resource utilization and conservation.

1.5 Scope of the Study

The objectives of the study was to examine the changes in land use over time from 1984 to 2021, determine the human activities occurring in the wetland and investigate the factors driving wetland encroachment. By doing so, the study aimed to enhance people's knowledge of the crucial role wetlands play in local livelihoods and increase their appreciation of their reliance on these ecosystems. The main cause of changes in the wetland ecosystem, including changes in biodiversity, habitat status, water resources, and agricultural activities, were hypothesized to be anthropogenic activities and their impacts. The research aimed to investigate the human activities carried out by communities living within a range of 1-4km from the wetland boundary. The buffer zones were limited to 4km because the utilization of wetland resources is typically lower with increasing travel distance. The study also examined the activities occurring on streams and rivers that flow into the wetland. The objective was to collect data and information that could be utilized to find a suitable balance between wetland preservation and meeting the needs of the local population.

1.6 Organization of the Study

The thesis is divided into six chapters. The first chapter serves as an introduction to the study, including the problem statement, research objectives and questions, scope and significance of the study, and background information. The second chapter consists of a literature review, while the third chapter provides details on the research methodology used. The fourth chapter presents the research findings, and the fifth chapter discusses these findings according to the specific research objectives. Finally, the sixth chapter summarizes the conclusions drawn from the study and offers recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents reviewed literature on wetland ecosystems and related effects due to human modifications. The literature explores the status of wetlands globally, regionally, nationally and at the local level. It also focuses on wetland values, threats, losses and strategies for wetland management. Resources reviewed include academic studies, reports by local, regional and international institutions. Finally, the chapter discusses the theoretical and conceptual framework.

2.2 Importance of wetlands

(Bridgewater and Kim, 2021) according to Ramsar Convention 1971; defines wetlands as areas that exhibit features such as marshes, fens, fringes of rivers and lakes, floodplains, estuarine deltas, ponds, river fields, and marine water areas. These areas are either naturally occurring or artificially created and are subject to periodic or permanent inundation. They contain static or flowing water, which can be freshwater, brackish, or saltwater, and their depth at low tide is no more than 6 meters.

Until recently, wetlands were commonly considered as barren lands, but they are now recognized as vital ecosystems that offer an array of advantageous services to humans, animals, and fish. These services are possible due to the distinctive natural attributes of wetlands, as identified by Brander & Schuyt (2004). These benefits are broadly classified into three areas, namely ecological, social, and economic functions, and are significant for global societies.

2.2.1 Ecological Benefits

Myers, (1996) stated that “wetlands have important functions in the hydrological and chemical cycles, as well as supporting extensive food webs and biodiversity”.

According to Murkin, et al. (2000) one of the significant ecological roles played by wetlands is biogeochemical cycling, which involves the transformation of nutrients within the biota, soil, water, and air. Wetlands offer natural filtration, which helps purify water by trapping pollutants such as sediment, excess nutrients, heavy metals, disease-causing bacteria, and synthesized organic pollutants, including pesticides. Therefore, water leaving wetlands is often cleaner than the water that enters it. Wetlands also provide a habitat for microbes that function in nitrogen and sulfur cycling due to their anaerobic nature, as noted by (Hagy et al., 2014).

Kingsford (2000) suggests that wetlands play a significant role in nitrogen and phosphorus removal from surface water, with most of the nitrogen present transformed into a gaseous form that supports specific plants and nitrogen-fixing bacteria. Wetlands also act as carbon sinks, storing carbon in their plant biomass and preserved peat instead of releasing it as carbon dioxide, a greenhouse gas that contributes to global warming caused by fossil fuel use such as coal and oil. Interestingly, coal is formed from plant material that accumulated under wetland conditions in swamps millions of years ago. Therefore, to mitigate the effects of climate change, conservation efforts should be prioritized instead of destroying wetlands, which would increase carbon dioxide levels.

According to Brazner et al. (2000), wetlands have an additional ecological significance as habitats for fish and wildlife. These areas are known for their high plant productivity, which is due to the presence of abundant water and nutrients in the soil. The vegetation, in turn, provides a valuable source of food and shelter for different types of animals. In particular, coastal wetlands are essential habitats for shellfish, such as clams and mussels, and for migratory and nesting shorebirds like sandpipers. Some mammals, such as fur-bearing creatures and muskrats, dwell in or around wetlands and utilize dwellings built from wetland vegetation. Research conducted during the 1970s and 1980s on bogs indicated that wetlands serve as refuges for rare plant species, including orchids and other endangered species. Many of these species face the threat of extinction if their habitat, which is primarily wetlands, is lost.

The prairie wetlands in the United States are highly valued wildlife habitats, particularly for migratory birds. Although they make up only 10% of the country's wetland acreage, they are critical for the breeding of ducks, with 80% of all ducks in the Great Plains using them as brooding sites. These wetlands also provide crucial nesting and staging habitats for various species of non-game migratory birds, including pelicans, whooping cranes, and shorebirds. Coastal estuaries and wetlands are essential for commercial and saltwater fish catches, with 66% to 90% of commercial fish and shellfish species on the Atlantic and Gulf coasts relying on them at some point in their life cycle, (Stewart Jr, 1982) Moreover, wetlands are vital for the spawning of salmon species on the Pacific coast.

In Tanzania and Kenya, freshwater wetlands are crucial in the production of fish, particularly in lake areas, contributing to 80% of the total output. Mangrove-filled estuarine ecosystems provide diverse habitats for various species to feed, breed, and grow, while also offering protection to a range of insects, birds, and small animals. These wetlands also serve as natural barriers against storms, erosion, and wind damage, stabilizing shorelines and enhancing the water quality of coastal stream estuaries (Materu et al. 2018).

Wetlands have an additional ecological function of improving the quality of water. They accomplish this by removing sediment, breaking down decomposing plant matter, and converting chemicals into forms that can be used. Wetlands are a good place for denitrification to occur, with both anaerobic and aerobic zones present. This process transforms nitrates into atmospheric nitrogen, which poses no pollution risk, as noted by Nyman, (2011). Furthermore, wetlands offer flood protection by temporarily storing water and slowing down its flow, which helps to decrease flood peaks, (da Silva et al., 2014)

Wetlands are significant in the treatment of sewage due to their ability to decompose human and animal waste, leading to the purification of water. In Uganda, the conservation of papyrus swamps and other wetlands near Kampala is crucial because they aid in the absorption of sewage and the purification of water sources. Non-biodegradable metals absorbed by wetlands sink to the bottom, accumulating over time as sediments decompose into bog (da Silva et al., 2014).

2.2.2 Social and Cultural Benefits

Wetlands have a diverse range of values, including cultural, scientific, recreational, and historical. For instance, the Coburg peninsula in Australia, the first Ramsar site, is owned by Aboriginal communities who conduct traditional ceremonies and use the wetlands for hunting and gathering. Wetlands offer recreational activities such as fishing, swimming, hunting, and sailing. They also have cultural significance in many societies, providing food, medicine, peat for fuel, and materials for making crafts and building homes. Additionally, the aesthetic, geological, ecological, and complex nature of wetland habitats make them ideal for academic research (Hossain and Szabo, 2017)

Rural populations in Africa heavily depend on wetlands, rivers, and springs as their primary sources of domestic water and for carrying out cultural practices. For instance, the Maasai community in Kenya utilizes wetlands to graze their livestock during the dry season, while the Bukusu people in Bungoma, Western Kenya, carry out important cultural functions, including funeral rites and circumcision ceremonies, in wetland areas. During the circumcision ceremony, young Bukusu men are taken to sacred wetlands where they are coated with mud to symbolize protection and warmth, marking their initiation into manhood.

The traditional perspective regarding wetland areas is that they should be left undisturbed and should not be enclosed, even if they are under private ownership. Moreover, herbaceous plants from wetlands can be utilized for constructing various structures such as houses and granaries. For instance, the Abaluyia people constructed their houses using sticks or reeds for walls and maize stalks or reeds tied to rings or grass for roofs as per Odero (2021).

Wetlands serve as a crucial resource for the traditional industries of indigenous communities, particularly in the production of items such as baskets and mats using materials from wetland plants. For example, amadura reeds and Insiola tree branches found in wetlands are used to make marachi sofas, which are dyed using natural dyes from wetland plants. However, the practice of grazing livestock in wetlands is becoming problematic due to the breakdown of social controls over these resources (Maithya et al., 2020)

The Njemps community, who live near Loboi swamps, have developed a sustainable and socially acceptable method of utilizing wetlands. During the dry season, they graze their livestock in the wetlands, but when the rainy season arrives, they and their animals move to other regions for grazing, and only come back when the dry season starts again. To avoid overgrazing, a council of elders regulates grazing and determines when it should resume in the wetlands, Kareri, (2018)

2.2.3 Economic benefits

Wetlands have multiple benefits that include ecological, social, and economic advantages. These natural areas are a rich source of decomposed organic matter and constantly recharged water that makes them valuable for agricultural purposes. For example, rice cultivation in wetlands is a crucial food source for more than half of the world's population, and African palm trees grown in these areas yield valuable oil for cooking and soap making as attributed to Silvius et al., (2000). In monetary terms, wetlands save large amounts of money, as evidenced by the example of New York City, where the filtering capability of wetlands has saved several billion dollars that would have been used to build new wastewater treatment plants. Finally, wetlands provide job opportunities and income for people through the harvesting of fish and shellfish, especially for communities living near these areas (Tollan, 2002).

Wetlands are of great value to people for various reasons. They support agriculture and provide job opportunities through fishing and shellfish harvesting (Mitsch and Gosselink, 2000). Additionally, wetlands protect against flood damage and related insurance costs, as well as human health and safety. Along the coast, they absorb wave energy and reduce erosion, which saves large areas of human settlement from destruction. Some communities are even required to protect their wetlands to maintain federal flood insurance in the USA.

Wetlands provide ecological, social-cultural, and economic benefits, including the provision of a rich source of decomposed organic matter and continuous water recharge for rice cultivation, which is a major dietary staple for over half of the world's population. They also yield valuable palm oil in Africa. Wetlands have flood control abilities that reduce damage to buildings, businesses, roads, and crops, saving cities billions of dollars in related insurance costs (Tollan, 2002). Coastal wetlands are also recognized for their role in storm protection, and some US communities are required to preserve mangroves to maintain federal flood insurance. Wetlands offer medicinal plants, hunting opportunities, and materials for honey collection, which can be used for local alcoholic beverages and medicines.

To supplement the produced vegetables, the Luhyas used to gather native vegetables (enderema) and fruits from marshes. These plants were treasured as they were used by locals to cure certain stomach ailments. These meant that wetlands were a common resource to the community where people could go and collect such plants without any restrictions. These also mirror the same situation in Kisii where a rare plant that was only found on wetland called *omoneke* could be harvested for medicinal purposes. This plant could be harvested and squeezed to obtain some fluid which could be applied on the cut umbrical cord of new born babies to enhance healing and prevent any infection. With the loss of wetlands such plants have disappeared and locals have been left with one option of purchasing pharmaceutical drugs at exorbitant costs which sometimes are not effective. With proper conservation of wetlands, locally available herbs can help save the local community economically.

Wetlands provide clay soil which has significant economic and cultural value in construction and ceramic production. Various types of clay were used for plastering the walls and floors of houses. The addition of wetland thatch grass to the clay mixture increased the durability of the houses. The choice of clay depended on its availability, but those obtained from wetlands were preferred. Clay soil was also utilized in the ceramic industry to make essential items like cooking pots. These products were sold both locally and internationally, empowering local communities economically.

Wetlands provide significant support for agricultural activities, as they can sustain farming activities all year round, regardless of whether it's a dry or wet season, (Brander and Schuyt, 2004). For instance, the Mwea rice scheme is a notable example of how wetlands can produce a large amount of rice. Additionally, the Yala swamp is capable of producing tons of rice. However, Ogut (1987) warns that draining wetlands for agriculture poses a significant threat to their sustainability.

2.3 Distribution of Wetlands

Wetlands occupy around 6% of the world’s land surface, consisting of over 12.1 million square kilometers of both inland and coastal areas, with 54% permanently flooded and 46% seasonally flooded, (Dobiesz et al., 2010). According to Boliko (2019), the majority of wetland areas can be found in Asia (31.8%), followed by North America (27.1%), Latin America and the Caribbean (15.8%), Europe (12.5%), Africa (9.9%), and Oceania (2.9%). However, natural wetlands have been declining worldwide in the long term, with inland and marine/coastal wetlands declining at a rate of approximately 35% between 1970 and 2015, which is three times the rate of forest cover.

Conversely, there was a noteworthy rise in the quantity of artificial wetlands, like reservoirs and rice paddies, which increased by nearly double over the same period, making up 12% of the world's total wetlands.

Wetlands, which were estimated to cover 6.4% of the world's land surface or about 8.6 million square kilometers, were identified by Russian geographers cited in the Ramsar Convention of 1995, (Bridgewater and Kim, 2021). Over half of this area (56%) is situated in tropical (12.6 million km^2) and subtropical (2.1 million km^2) regions. Wetlands can be sorted into various categories, including lakes (2%), bogs (30%), fens (26%), swamps (20%), and floodplains (15%), according to the Ramsar Convention's 1998 report. Mangrove areas across the world are roughly 25 million hectares, while coral reefs take up about 60 million hectares. The most extensive remaining wetlands are found in high latitudes and tropical regions.

With the exception of Antarctica, wetlands are present on all continents, including the Amazon River basin and the west Siberian plains, which are among the world's largest natural wetlands. Additionally, the Pantanal, found in Brazil, Bolivia, and Paraguay, is a significant wetland. The utilization of remote sensing and mapping technologies since the 1980s has resulted in an increase in the estimated size of global wetlands (Davidson and Finlayson, 2019)

2.3.1 Wetlands in Africa

In Africa, the coverage of inland wetlands is around 1% of the overall land surface, with the most notable ones being the swamps of the Congo River, the Sudd in the upper Nile, the Lake Victoria basin swamps, the Chad basin swamps, and the flood plains and deltas linked to significant rivers such as the Niger and Zambezi.

On the other hand, in Eastern Africa in the year 2020, the wetlands cover roughly 4% or 20 million square kilometers of the total area and the significant wetland areas in this region include the Lake Victoria basin, the Rift valley, and the floodplains and deltas of major rivers like Tanzania's Rufiji and Kenya's Tana (Schuijt, 2002).

According to Keter, (1992), wetlands make up around 2% to 3% of Kenya's total surface area and this means the area fluctuates seasonally and they are an important resources that offers valuable goods and services. There are several significant wetlands in Kenya, including shallow lakes like Nakuru, Naivasha, Magadi, Baringo, Amboseli, Kamnarok, and Elmentaita in the Gregory Rift Valley. Other wetlands can be found around Lake Victoria and in mangrove forests in the coastal region. There are also human-made wetlands, such as dams built for hydropower, water supply, and wastewater treatment. Wetlands in Kenya can be classified into five major types based on their topographic features, namely marine, deltaic, riverine, lacustrine, and plateau, with two minor types being artificial wetlands and montane peat bogs. These wetlands are mainly distributed in well-watered regions, coastal areas, highlands, and around Lake Victoria in Eastern Africa. A map below illustrates the distribution of wetlands in the region.

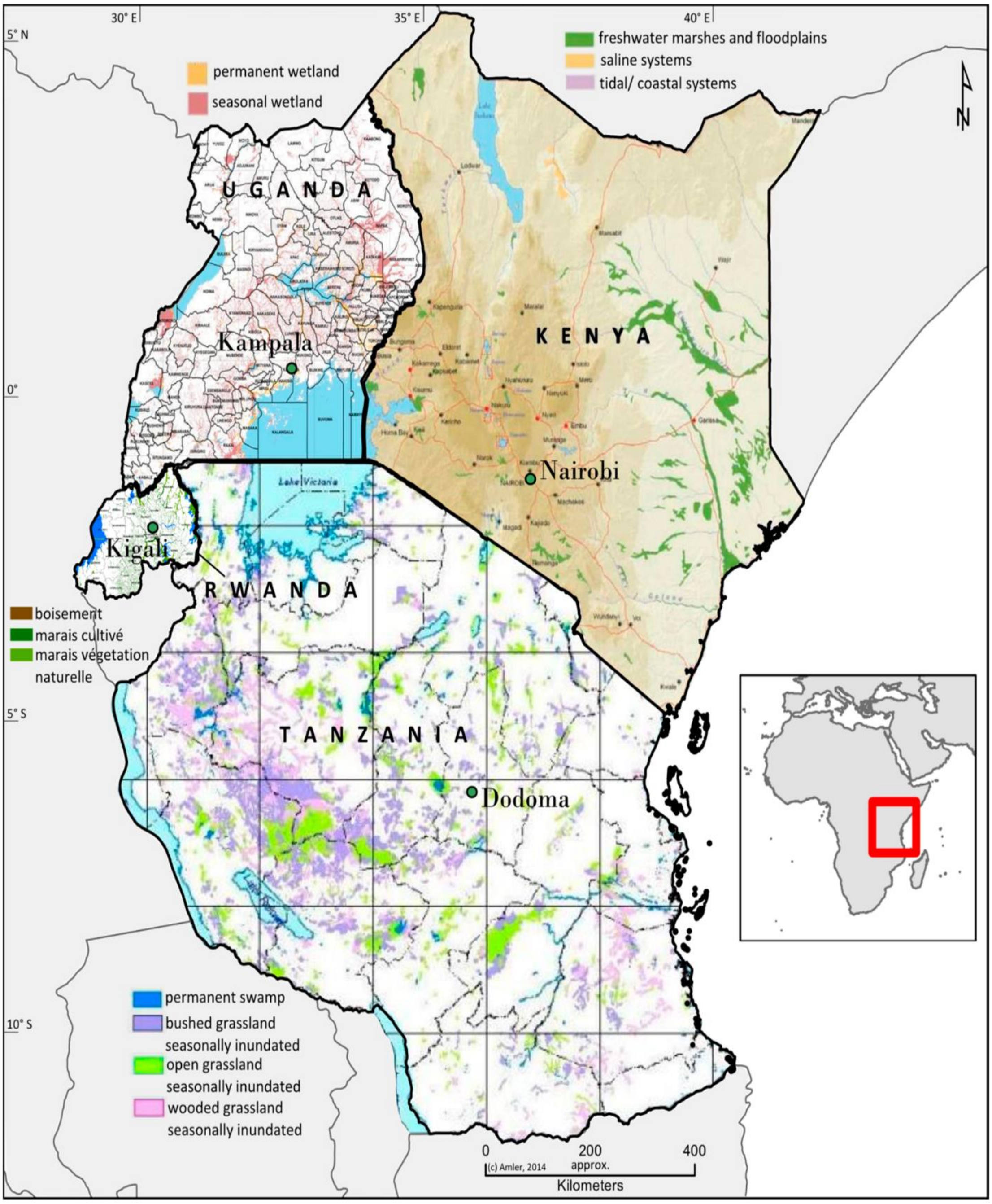

Figure 2.1: Distribution of Wetlands in Eastern Africa

Source: Kenya Wetland Atlas, 2020.

2.4 Threats to Wetlands

Wetland ecosystems in Latin America and the Caribbean are at risk due to various factors such as pollution, hunting, and drainage for agricultural purposes. On the other hand, in East Asia, wetlands are under threat due to industrial development and human settlement. Wetlands were not considered valuable for agriculture and other activities until about 20 years ago, and hence were protected. However, in recent decades, there has been an unprecedented conversion of wetlands in all developing countries. Wetlands in Asia are particularly vulnerable, with 50% of them facing severe threats, and the numbers rising to 86% in Malaysia and 82% in Bangladesh. Xu et al., (2019)

2.4.2 Regional Context

The majority of wetlands in Africa are facing various threats, including drainage for agriculture, human settlement, over-fishing, industrial development, pollution, and wildlife extinction. Hoyer et al. (2020), the Jonglei Canal project in Sudan is expected to reduce the size of the Sudd swamp by 40%, which will result in lower water tables and drier conditions. Deforestation is another major indirect threat to wetlands in Africa, as it leads to siltation, which is a common problem in the Niger and Congo forests. In South Africa, wetland resources are threatened by commercial hunting, commercial forestry, and human settlement, as noted by Masese (1996). Wetlands in Rwanda are also at risk due to the mining of swamp peat for energy, while dams such as the Aswan High Dam on the Nile, Kainji on the Niger, and Kariba on the Zambezi pose significant threats to wetlands, according to Finlayson et al. (1999)

2.4.3 Local Context

In Kenya, wetlands face various threats such as agricultural activities, deforestation and destruction of catchments, overgrazing by livestock, human settlements, and sedimentation, which lead to conflicts between humans and animals. During the dry season, wetlands provide crucial pasture for livestock-dependent communities. Thornton et al., (2007) highlights that river floodplains and estuarine wetlands, due to their flat terrain, are more vulnerable to urbanization and development than upland areas. This often leads to the clustering of human settlements in these wetland ecosystems. For example, there are approximately 60,000 ha of mangroves along the Kenyan coast, with 67% found in Lamu County. Mangrove forests have suffered a loss of about 10,310 hectares due to factors such as conversion to other land uses, overexploitation, and pollution. Human settlements are posing a threat to wetlands, mainly due to the watershed-related impacts of urban development. As a result, wetlands are being polluted and their ecological integrity is being threatened. Moreover, commercial, municipal, and institutional wastes are being dumped in wetlands, leading to eutrophication and algal blooms. These impacts are most pronounced in wetlands near major agricultural areas.

Table 2.1 below shows some of the identified threats to Kenyan wetlands.

Table 2.1: Factors that Threaten Wetlands in Kenya

Threat	**Effect**
Agriculture	Decreased ecological functioning Loss of biodiversity
Deforestation and catchment destruction	The deterioration of natural living environments, the reduction of the variety of plant and animal species, and changes in water distribution patterns.
Livestock overgrazing	Loss of habitat
Human settlement and encroachment	The destruction of habitats leading to a reduction in the availability of breeding grounds and the loss of biodiversity, which in turn can impact ground water recharge and contribute to the extinction of valuable species.
Human-animal conflict	Key species loss
Pesticide and herbicides	The accumulation of harmful substances in fish can pose a threat to human health. Additionally, it can lead to the death of fish, as well as the extinction of important species.
Siltation and sedimentation	Smothering of aquatic organism Ecological change Habitat loss

Source: (National Environmental Management Authority, 2010: page 15)

2.5 Trends on Wetland Loss

Wetlands can be lost in small increments or in large areas, and the cumulative loss can be significant over time. Boliko, (2019) reports that the average yearly rate of natural wetland loss is estimated at -0.78%, which is more than three times faster than the average yearly rate of natural forest loss (0.24%) from 1990 to 2015. The natural wetland loss rate has increased from -0.68% to -0.69% per year between 1970 and 1980 to 0.85% to -1.60% per year since 2000.

2.5.1 Global Trends on Wetland Loss

Wetland destruction is a pressing concern worldwide, with an estimated 50% of original wetlands already lost due to human activities. The current condition in Europe regarding wetlands is extremely concerning, with only 58 wetlands out of the 318 documented in the 17th century still in existence today. To put it differently, Europe has lost a significant number of wetlands since the 17th century, with only a small fraction of the previously recorded wetlands remaining. The United Kingdom and the Netherlands have lost a staggering 69% of their wetlands by 1980. These losses are primarily due to human activities as per Davidson, (2014).

The statement above is reinforced by the data presented in Table 2.1, which illustrates the extent of wetland depletion in various regions across the globe. In other words, the table provides evidence to support the assertion made earlier by demonstrating the scale of wetlands loss in certain areas

Table 2.2: Percentage Loss of Wetlands in Some Locations in the World

Region	**Percentage loss (%)**	**Source**
United States	53	(Chathain *et al.*, 2013).
Lower Great Lakes- St. Lawrence River	71	(Coyne, 2014)
Prairie Potholes and Sloughs	71	(Tobin and Deshek, 2001)
Pacific Coastal and Estuarine Wetlands	80	(Global Nature Fund, 2002).
Australia	>50	Australia Nature Conservation Agency (1996)
Swan Coastal Plain	75	National wetlands working group (2010)
Africa	>33	UNEP (2005)
River Murray Basin	35	(TEEB, 2013).
New Zealand	>90	Dugan (1993)
Philippine Mangrove Swamps	67	Dugan (1993)
China		LU (1995)
Europe	>90	Estimate

Source: Mitsch and Gosselink, (2000).

2.6 Causes of Wetland Loss

Liverman and Cuesta, (2008) provided definitions for land use and land cover, with the former referring to human activities on land such as grazing and agriculture, including social aspects like subsistence or commercial farming. On the other hand, land cover encompasses the physical and biological components that cover the land, including vegetation, water, and bare soil, which are typically determined by human decision-making. Land use decisions play a significant and direct role in wetland loss, and unsustainable land practices aimed at fulfilling short-term individual needs pose a significant threat to wetland ecosystems, (Maltby, 2022) the failure to consider the benefits provided by wetlands in planning policies and decisions has led to the rapid deterioration and depletion of wetlands worldwide. To address this concern, the Ramsar Convention and other initiatives have been developed with the aim of mitigating the loss and degradation of wetlands. In summary, the neglect of the services offered by wetlands in planning policies and decisions has had severe consequences, but steps are being taken to reverse this trend through international initiatives.

The increasing human population and the consequent demand for food production have exerted immense pressure on wetlands worldwide, (Smith et al., 2016), resulting in their degradation or loss due to human activities. Wetland loss refers to the conversion of wetlands to non-wetland areas, whereas wetland degradation refers to the impairment of wetland functions due to human activities. Wetland loss is a direct outcome of wetland degradation, which leads to a change in the amount of wetland resources compared to a baseline. The degradation of wetlands has multiple negative impacts, including a reduction in biodiversity, changes in water quality/flow patterns, a scarcity of wetland resources, a loss of aesthetic, cultural, and spiritual values of wetlands, and the emergence of new species. Unfortunately, planning policies and decisions frequently disregard the critical services offered by wetlands, leading to their fast degradation and loss worldwide. This issue has spurred the Ramsar Convention and other initiatives to address wetland conservation.

2.6.1. Increasing Human Population

The expanding human population is a significant factor that has led to the depletion of natural resources. In order to meet the growing demand for resources, people are exploiting them at an accelerated pace. It is crucial to consider land use decisions at the household level to ensure sustainability. As the world's population continues to increase, there is mounting pressure on the earth's resources to support a wide range of social and economic activities, not just basic needs. Societies are becoming more organized to address these demands. The UNEP predicts that developing countries will have a population of around eight billion by 2025 and nine billion by 2050 (Smith et al., 2016)

2.6.2 Infrastructural Development

Human activities and disturbances have had a negative impact on wetlands, leading to their loss and decreased value and function (Tiner, 2003a). Direct effects within wetlands include building construction, burning, changes in water levels, and road and bridge construction (Mensing et al., 2008). Poorly designed roads can cause an increase in sediment loads that suffocate aquatic life and alter the geometry of wetlands and streams. This also leads to the introduction of heavy metals and other toxic substances attached to sediment particles Peng et al., (2009). Road and bridge construction operations can also disrupt habitat communities, displace sensitive species, and provide habitat for non-native species. Soil compaction caused by road construction can lead to a significant amount of dust that covers the leaves of nearby vegetation, hindering the photosynthetic rate of plants and reducing foliage gaseous exchange Lalu, (1964). According to Kanyesigye, (2017), the presence of burrow pits adjacent to wetlands can lead to a decline in water quality. This can occur due to the accumulation of sediment, which raises the level of turbidity in the water and has a significant impact on the variety of submerged vegetation.

The utilization of herbicides, soil stabilizers, and dust palliatives along roadways can harm plants present in wetlands. Wetlands, which have been historically considered as wastelands and treated as public property, are at risk of being excessively depleted, owing to the perception that they hold no significant value. Lack of enforceable property rights has led to increased pressure on wetlands from human activities such as tourism and recreation, which can create infrastructure such as hotels and golf courses, leading to increased waste and disturbance. Marine light pollution is also on the rise, with over a fifth of global coastlines exposed to artificial light at night. The presence of non-native species in wetland ecosystems, which can pose a threat to their biodiversity, is amplified by the influx of tourists.

2.6.3 Agriculture

Hood and Larson, (2015) have identified agriculture as a significant contributor to the depletion of freshwater and estuarine wetlands. Agricultural activities have both direct and indirect impacts on wetlands, including the direct conversion of wetlands into agricultural land and the indirect loss of wetlands due to the extraction of water from rivers and streams for irrigation. Moreover, wetland functions can be impaired by agricultural practices that cause salinization, sediment deposition, eutrophication, and pollution from pesticides and chemical residues. Poor agricultural practices in upland areas can also cause soil erosion and the runoff of agricultural waste, which can affect wetlands. These pressures can lead to wetland degradation and a decline in its capacity to provide vital ecosystem services.

The accumulation of animal waste and excessive fertilizers in wetlands can trigger eutrophication, which causes an overgrowth of algae, leading to a decline in submerged vegetation. In addition, during dry periods, the physical disruption of wetlands via tilling and compaction can encourage the prevalence of non-native plant species and ruin the seed bank. Wetlands are frequently impacted in developing nations where water resources are scarce, and there is a high demand for agricultural production. As an example, roughly half of the wetlands in Eastern South Africa have been degraded or lost due to agricultural activities, whether for commercial or subsistence purposes. (Moomaw et al., (2018) undertook a study to evaluate how the cultivation of crops affects the value, function, services, and products of the Nakivubo wetland in Uganda. The study discovered that wetland resources were excessively exploited, with crop cultivation dominating over 80% of the wetland. Dixon et al. (2008) study on the preservation of seasonal wetlands and their contributions to people's livelihoods in Malawi. The study revealed that active farming for crop cultivation during the dry season, rather than allowing natural vegetation to remain dormant, resulted in greater water extraction from the wetland, especially when watering cans or treadle pumps were employed. When the entire surface area of a wetland is used for farming, its capacity to operate as a wetland is compromised, and the water table may be lowered.

Kenya's wetlands surrounding Lake Victoria constitute nearly 37% of the country's total wetland area (2,737,790 hectares), with the largest one being the Yala swamp, which covers an area of about 21,765 hectares, including water bodies like Lake Kanyaboli, Lake Nyamboyo, and Lake Sare1 as per a research done by Maithya et al., (2020) . While some wetlands within national parks are adequately safeguarded, many swamp forests outside of gazetted areas remain vulnerable and face the threat of complete annihilation due to the high population density. Human intervention, such as drainage for agriculture, diminishes the size, biodiversity, and aesthetic worth of wetlands. For example, the Yala, Nyando, and Sondu-Miriu swamps on the Kana plains are being drained for agricultural activities, with an estimated 14,000 hectares of the Yala swamp expected to be transformed for productive purposes. Furthermore, rice and sugar cane production has resulted in 900 hectares of the Kano plains being repurposed. In recent times, Dominion Farm Ltd, a subsidiary of the Dominion Group of companies based in Oklahoma, USA, has reclaimed 2,300 hectares of the Yala swamp in Siaya district (Kareri, (2018).

The negative effects of farming activities, including the clearance of wetlands for cultivation, the use of agrochemicals such as pesticides, and overgrazing, have adverse consequences on the surviving wetlands. This includes an excess of nutrients, resulting from the runoff of fertilizers, pesticides, and soil erosion. Additionally, wetlands with shallow water levels are being excessively cultivated for crops like sugar cane and yams, leading to the depletion of the already limited wetlands. After two years of draining wetlands for agriculture, some wetlands become unproductive and are subsequently abandoned. The reclamation of wetlands has been observed to reduce the number of permanent springs and lower the groundwater yield in wells.

On the other hand, excessive grazing can cause damage to wetland vegetation, soil composition, and water quality, (Allen and Feddema, 1996). Kingsford, (2000) research found that South African wetlands are at risk due to cattle trampling on vegetation and soil, which leads to gully erosion and wetland loss. Unregulated grazing in wetlands can also cause the loss of hydrophytes, which serve as water filters, reducing the wetland's ability to effectively purify water.

The excessive use of urea and manure wastes from grazing animals can lead to high levels of nutrients entering the water, which contributes to the process of eutrophication. Livestock overgrazing in riparian areas can also result in a reduction in vegetation along the stream banks, which can cause runoff water to not be properly filtered, increase stream temperatures, and lead to a lack of food and cover for aquatic life. It can also destabilize stream banks and result in erosion, leading to sedimentation downstream Faulkner et al., (2011). Kirkman et al., (1996) overgrazing can also have negative effects on wetlands, such as soil compaction, reduced seed germination rates, and destabilization of stream banks.

2.6.4 Effects of Eucalyptus Trees on Wetlands in Kisii County

According to a study published in the International Journal of Agriculture and Biology, eucalyptus, a commonly cultivated species in agroforestry, consumes large amounts of water as confirmed by research conducted in Pakistan Bayle, (2019). This indicates that the exotic species consumes a significant amount of water, creating competition not only for other plants and crops but also for human use in domestic and industrial activities, as well as for livestock and wildlife. The lack of effective management and conservation of water resources can lead to a severe environmental crisis for the human population.

In Kisii County, the ecosystem has been severely impacted by the extensive planting of eucalyptus trees resulting in many swampy areas drying up. According to the NEMA Director of Kisii County, who was contacted on 22nd March 2021, four out of 22 springs along River Rigathi have already dried up, forcing the residents to travel long distances in search of water. It is paradoxical that the uncontrolled growth of eucalyptus trees is putting the rivers that communities rely on for water at risk of drying up. The trees are mainly grown for commercial purposes and to meet the high demand for wood fuel, owing to their fast growth.

Eucalyptus trees are known to be heavy water consumers and can cause damage to the environment, and even fatalities, as reported by Bayle, (2019). These trees are criticized for competing with native plants and not supporting them. Due to their inflammable substances, planting eucalyptus trees away from residential areas is recommended to prevent fire accidents. In Ethiopia, eucalyptus was believed to dry up rivers and wells, leading to a declaration in 1913 to partially destroy all standing eucalyptus and replace them with mulberry trees Sousa et al., (2015)). In Italy, eucalyptus is grown in swampy areas to eradicate malaria by draining water from swamps and destroying the breeding ground for malaria vectors. While this may seem beneficial to residents who may not want to use insecticides, the impact on the swamp's biodiversity was overlooked, leading to a blow to the ecosystem (Lindsay et al. 2004).

The late Professor Wangari Mathai, a well-known environmental activist in Kenya and founder of the Green Belt Movement, was strongly opposed to the growth of eucalyptus trees along river valleys and water catchment areas. She argued that the species was being promoted excessively for commercial gain (Science Development Journal 2009). Despite efforts by the National Environmental Management Authority (NEMA) to remove eucalyptus trees from river banks and wetlands, the local population has largely ignored the warnings and continues to plant the trees, disregarding the negative effects it has on the environment and their livelihoods Golding, (2014)

2.6.5 Water Pollution

Wetlands can improve the quality of surface water by absorbing pollutants; however, there is a limit to their ability to do so. Wetlands are often degraded by common pollutants such as fertilizers, animal waste, sediments, hydrocarbons, road salt particles, and heavy metals, (Keddy et al. 2009). Pollutants that can disturb the proper functioning of wetlands may originate from point sources like municipal waste or non-point sources like agricultural and urban runoff, (Hanson et al. 2008). Such sources can contribute materials to surface water and groundwater, and consequently, disrupt wetland functions. Wetlands can also be severely impacted by pollutants from marine and boat sources, including hydrocarbons and toxic chemicals and solvents. Waste from landfills and their associated waste water treatment plants can be a significant source of nitrogen and phosphorus pollution in wetlands, resulting in the growth of algal blooms Mironga, (2005). Additionally, discharging human waste materials into wetlands can increase nutrient levels, leading to eutrophication Fink and Mitsch, (2004). The release of sulfurous oxide, nitrous oxide, heavy metals, and volatile pesticides into the atmosphere via agricultural, industrial, and vehicle emissions can also affect aquatic life in wetlands through wet and dry atmospheric deposition.

Research shows that Lake Victoria is currently facing a serious problem of high levels of nitrogen and phosphorous. This problem is largely caused by human activities such as agriculture, livestock rearing, and disposal of industrial and domestic waste, which require the use of significant quantities of synthetic chemicals such as pesticides and fertilizers. The amount of phosphorus that is discharged into the Lake Victoria basin each year is approximately 22,000 tons, and it is believed that about 3,000 tons of this comes from animal manure and 132 tons comes from domestic waste. Although animal manure and domestic waste are responsible for contributing only small amounts of phosphorus to Lake Victoria, they contribute significantly to nitrogen inputs. These sources account for over 40,000 tons of nitrogen inputs per year, which is more than three times the amount of nitrogen contributed by synthetic fertilizers. The need to intensify agricultural practices due to population growth and pressure on land has had negative consequences on the environment as attributed by Mironga, (2005).

2.6.6 Urbanization

The process of urbanization causes modifications to wetlands that affect their hydrological connections, alter habitats, change water table levels and soil saturation, contribute to pollution, and ultimately have an impact on the diversity and number of species that inhabit them, (Faulkner and Bichan, 2015).

The primary reason for wetland alteration is urbanization, which indirectly causes the loss of wetland acreage and degradation, including changes in water quality, quantity, and flow rates. Pollutant inputs increase and species composition changes due to the introduction of non-native species and disturbances. Housing development and urban sprawl rapidly convert wetlands and agricultural land, leading to flooding, which can result in loss of life. Additionally, urbanization results in the construction of impervious surfaces, such as roads, buildings, and parking lots, which prevent rainfall from infiltrating the soil, carrying sediment, organic matter, pesticides, fertilizers from lawn gardens, road salt, and debris into urban streams and wetlands.

2.6.7 Mining

According to Beach et al., (2009)mining activities have lasting adverse effects on wetland values and functions, including water quality and quantity and aquatic life. In central Florida, phosphate mining resulted in the loss of several acres of wetlands, as found in the research by Mitsch and Gosselink, (2000). High metal concentrations and acidity can modify the biotic community, leading to the death of aquatic life, as indicated by Bosselman, (1989)

Mining activities that expose wetland soils convert original sulphides to sulphuric acid, leading to acidification of the wetland environment, (Maltby, 2009) Peat mining operations destroy a portion of the wetland selected for mining, including the removal of vegetation, wetland drainage, and road construction for equipment. These practices, as reported by the United States Environmental Protection Agency (USEPA, 1995), contribute to wetland pollution. In South Africa, active and abandoned mine sites introduce higher acidity and heavy metals into the wetland environment via surface runoff and the drainage of acid into water bodies, resulting in the death of aquatic life over time.

2.6.8 Globalization

The term "globalization" refers to the interconnectedness of national economies through international trade and financial activities, as stated by the International Monetary Fund (IMF) in 2002. The improvement in transportation and communication has enabled the transfer of people, commodities, and ideas worldwide. As a consequence, there has been a rise in economic migration, an increase in tourism and business travel, and the distribution of goods produced in low-cost areas to consumers in remote locations at higher prices, Achankeng (2003).

As a result, low- and middle-income economies may resort to intensifying agricultural activities on wetlands to increase production for commercialization, which can ultimately cause harm to these ecosystems. While globalization can provide advantages such as economic progress and reduction of poverty, it also poses a risk of exacerbating environmental pressures on wetlands.

Globalization is known to have an impact on wetlands through changing consumption patterns. The emergence of a middle class in developing nations has resulted in shifts in energy and food consumption patterns, leading to a rise in demand for infrastructure, industrial goods, water, and waste production, as well as an increase in greenhouse gas emissions, (Odero and Odenyo, 2021) and Boliko, 2019). Meat consumption is one such pattern that has significant implications for resource demand, including the need for land for pasture production for animal feed, and increases in water usage, (Mensing et al., 1998)

The high demand for agricultural products that thrive better in Kisii region such as sugarcane and bananas have created high market demand where the locals have resorted to intensify the produce for commercial purposes. This has resulted to expansion of agricultural areas into the wetland area to meet the surging demand from other regions in Kenya and beyond. To increase the produce and enhance quick maturity the growers resort to application of manufactured fertilizers like D.A.P which eventually find their way into the water resources resulting to water pollution and loss of biota Mironga, (2005).

2.7 Assessing Change Detection in the Wetlands

It is crucial to map wetland ecosystems to identify long-term land use and cover patterns to improve the detection of changes. This is accomplished by use of satellite images acquired repetitively over long periods of time. The images are remotely acquired which are then processed to visualize the changes which have taken place during a specified period of time, Lu et al., (2004). Some of the tools used to achieve this are discussed as follows;

2.7.1 Use of Remote Sensing Technology for Land Use Land Cover Change Detection

Remote sensing is a method that utilizes devices that do not touch the object to gather information about it, and it is an important tool for obtaining data on land use and cover changes due to its capability for synoptic viewing and repetitive coverage. At least two data sets from different periods are required for detecting changes in land use/cover. Landsat satellite images are now widely used in land use and land cover studies, with an accuracy rate of around 80% to 90%, due to their availability over the past three decades and 30 m pixel size resolution. Many studies on wetland mapping have shown that Landsat satellite images are suitable. The archived remotely sensed data can be utilized to detect changes in land use/cover caused by both natural and human factors Lu et al., (2004)

The use of Landsat multispectral imagery has proven to be extremely useful for monitoring changes in wetland ecosystems due to its ability to provide uninterrupted coverage since the 1970s, and its inclusion of bands that can detect changes in vegetation and soil moisture. Remote sensing provides an unparalleled opportunity to examine the spatial and temporal patterns of these changes, which is difficult to achieve with traditional field-based methods. By comparing early and current satellite images, changes in the landscape over a specific period can be detected. To understand wetland dynamics, researchers need to make observations at multiple spatial and temporal scales, which can be achieved by using satellite images. Satellite images have the ability to identify and illustrate changes in land use and coverage, whether on a small or large scale, and how these alterations can affect the functioning of wetlands according to Lu et al., (2004)

The classification of wetlands has been accomplished using various datasets, including aerial photos, SPOT data, and Landsat data. Among these, Landsat-based classification is considered to be the most accurate because of the sensitivity of Landsat bands (Civico et al., 1992). The Landsat TM and ETM+ sensors have seven similar bands, with the ETM+ having a higher resolution of 60m in Band 6. Band 1 of the TM sensor can detect water depth in coastal areas, differentiate between soil-vegetation types, and distinguish between forest types. Band 2 detects green reflectance from healthy vegetation, and Band 3 can detect chlorophyll absorption in vegetation. Band 4 is particularly useful for detecting near-infrared reflectance peaks in healthy vegetation and water-land interfaces. The two mid-infrared bands are valuable for studying vegetation and soil moisture and differentiating between rock and mineral types. Lastly, the thermal-infrared band is useful for thermal mapping and studying soil moisture and vegetation, (Ozesmi & Bauer, 2002).

Table 2.3: LandSat TM bands and Wavelength Ranges

Spectral band	Wavelength	Resolution(m)	Use
Band1-blue green	0.45-0.52	30	Distinguishing soil from vegetation, deciduous from coniferous vegetation
Band 2-green	0.52-0.61	30	Assessing plant vigor.
Band 3-red	0.62-0.69	30	Highlights the significance of vegetation gradients on inclines.
Band4-reflected infra-red	0.76-0.90	30	Emphasizes biomass content and shorelines
Band5-reflected infrared	1.55-1.75	30	Differentiates between the moisture levels of soil and vegetation.
Band 6-thermal	10.40-12.50	120	Thermal mapping and moisture estimation
Band 7 Mid IR	2.08-2.35	30	Discrimination of mineral and rocks and vegetation moisture analysis.

Source-http://landsat.usgs.gov/tools 2010

2.7.2 Geographic Information System (GIS)

The use of Geographic Information Systems has become more and more important in the management of wetlands. When combined with remote sensing techniques, GIS is useful for rapidly evaluating wetland degradation and water pollution. Additionally, GIS can help to create spatial models of wetlands, taking into account population changes, transportation networks, and development activities. The use of GIS technology offers a range of benefits for environmental management, such as identifying land use and land cover, conducting overlay analysis, buffering, and creating thematic maps.

2.8 Strategies for Land Use / Cover Change Detection

It is essential to use multiple data images to track land use changes and determine the factors driving them. The choice of an appropriate change detection algorithm is critical to effective monitoring, Jensen (1996). Kenya is experiencing rapid human-induced land use changes, which can have significant impacts on the water and energy balance, climate conditions, biodiversity, and food security. Therefore, monitoring and assessing the state of land use and cover is crucial to understand the underlying causes of changes and plan for sustainable management of natural resources. This information is essential for effective land use planning and management, (Singh et al., 2022).

2.8.1 Supervised and Unsupervised Classification

Richards (1993) emphasized the importance of using supervised classification to obtain quantitative information from remote sensing images. This method is particularly useful when the analyst has prior knowledge of the study area. In contrast, unsupervised classification is more appropriate when the study area is unknown.

During supervised classification, the analyst uses known pixels to create characteristic parameters for each class of interest. These parameters are then utilized to label all image pixels according to trained parameters. The most frequently used technique for supervised classification is maximum likelihood classification (MLC), which assumes that each spectral class can be characterized by a multivariate normal distribution.

The procedure of unsupervised classification entails using clustering techniques to classify image data without any prior knowledge of the classes, as highlighted by Richards (1993). It is beneficial for identifying the number and position of spectral classes. A popular unsupervised classification method is the migrating means clustering classifier (MMC), where each pixel is assigned to unknown cluster centers, and then moves from one center to another Richards & Richards, (2022), however, in the current study, maximum likelihood supervised classification was utilized because the researcher possessed some knowledge of the study area's location and identity.

2.9 Wetland Management and Institutional Frameworks

Different policies and programs have been established to address the impacts on wetlands and improve their quality and quantity. These measures promote cooperation both nationally and internationally to develop strategies for minimizing the effects and promoting the wise use of wetland resources, according to Mensing et al., (1998) Policymakers have proposed a range of regulations and policies to achieve the goals of wetland mitigation and compensation. Several conventions and protocols have been created to conserve wetlands, including: -

2.9.1 The Ramsar Convention on Wetlands of International Importance

The Ramsar Convention, adopted by Kenya in June 1990, seeks to safeguard and manage wetlands. It mandates countries to encourage the sustainable use of wetlands in their territories and establish wetland nature reserves, whether or not they are on the Ramsar list. Presently, 159 countries have become parties to the convention, and the Ramsar list includes 1,838 wetland sites that cover a total area of 161 million hectares deemed important globally, MacKay et al., (2009).

The Ramsar convention was established with the objective of promoting the sustainable use and protection of wetlands through both national and international cooperation. The convention was originally adopted in 1971 and subsequently revised in 1982, 1987, 1990, 1992, 1995, 1998, 2002, and 2013. It provides a framework for member parties to collaborate on the conservation and management of wetlands and their resources. The parties to the convention are committed to promoting the wise use of wetlands through national land use planning, policies, laws, management actions, and public education. They also designate suitable wetlands for inclusion on the Ramsar List of Wetlands of International Importance and ensure their effective management. In addition, they collaborate internationally on transboundary wetlands, shared wetland systems, shared species, and development projects that may affect wetlands. There are currently 171 contracting parties to the convention, and over 2,300 wetland sites, covering more than 250 million hectares, have been designated for inclusion in the Ramsar List.

2.9.2 The Convention on Biological Diversity (CBD)

The Convention on Biological Diversity (CBD), which was adopted during the 1992 Earth Summit in Rio de Janeiro, is an international agreement with the primary goal of conserving biological diversity, promoting the sustainable use of its components, and ensuring fair and equitable sharing of the benefits arising from the use of genetic resources. Article II of the CBD focuses on incentive measures to promote the conservation of biological diversity. This article requires each contracting party to adopt measures that are economically and socially sound and encourage the conservation and sustainable use of components of biological diversity. The CBD recognizes the significance of wetlands, as indicated by the definitions of biological diversity and ecosystems in Article 2. The term biological diversity refers to the differences among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems, as well as their ecological complexes. It encompasses diversity within species, between species, and of ecosystems. Ecosystems, on the other hand, are described as dynamic combinations of plant, animal, and micro-organism communities, as well as their non-living environment, that interact as a functional unit. According to the Convention, State Parties are mandated to create national plans, strategies, or programs for the sustainable use and conservation of biological diversity, and to incorporate these measures into policies, programs, and plans that are either sectoral or cross-sectoral according to Denny, (1994)

2.9.3 Sustainable Development Goals (SDG’s)

The SDGs established by the United Nations recognize the crucial role of wetlands in managing and restoring water-related ecosystems while addressing water scarcity and risks. Wetlands play a significant role in mitigating water, food, and climate-related issues. Several SDGs are relevant to wetlands, including:

First wetlands help to End hunger, achieve food security and improved nutrition and promote sustainable agriculture. Wetland paddies are utilized for growing rice, which is a crucial food source for roughly three billion people globally. Coastal marshes and estuaries play a vital role as breeding and nursery areas for numerous commercially significant fish species. Additionally, 70% of the total global freshwater withdrawal is utilized for irrigation purposes in agriculture Boliko, (2019)On average, an individual consumes 19kg of fish per year.

Secondly wetlands ecosystems Ensure availability and sustainable management of water and sanitation for all is realized. This is crucial role wetlands play in maintaining freshwater resources, aiding in the replenishment of underground water reserves, and effectively filtering and purifying contaminants like pesticides, fertilizers, heavy metals, and industrial waste from water.

Wetlands also create cities and human settlements that are sustainable, resilient, safe, and inclusive. To effectively perform this ecological function, wetlands act as natural absorbents that soak up rainwater, offering protection against river and coastal flooding and decreasing the reliance on artificial infrastructure. They additionally assist in preventing drought, safeguarding coastal regions as habitats for fish breeding, and controlling the transport of sediment, resulting in land creation and the stability of the coastal zone.

Wetlands on the other hand, help in combating global warming and its catastrophic consequences. They play a pivotal role in carbon sequestration, as peatlands alone store a greater amount of carbon than all the world's forests combined. They also provide protection to coastal regions by mitigating the effects of rising sea levels, serving as a natural barrier against storm surges and offering erosion control.

Wetlands continuously help in Protecting and utilizing the oceans, seas, and marine resources in a way that ensures sustainable development. Without wetlands, there would be considerable alterations in the processes of water, carbon, and nutrient cycling. The water cycle is essential for maintaining biodiversity and the functioning of all ecosystems on land and near the coast, taking place above and below the Earth's surface.

Lastly wetlands help in the preservation, rejuvenation, and sustainable utilization of land-based ecosystems, effectively manage forests, prevent desertification and reverse land degradation, and halt the loss of biodiversity. To this effect, **w**etlands have been proven to provide benefits per unit area that are significantly greater than those of other ecosystems. The primary advantage that wetlands offer is the improvement of water security.

2.11 Regional Context

RAMCEA is a regional initiative located in Uganda and is composed of six member states, which are Kenya, Uganda, Burundi, Rwanda, Djibouti, and Tanzania. Its main goal is to support the East African community nations and other related groups and institutions to improve the implementation and enforcement of the Ramsar Convention in their respective countries, while following the convention's wise use principle.

According to Mironga, (2005) report, wetland management in the Eastern Africa region faces challenges such as scattered regulations due to sectoral laws, insufficient funding, and lack of education and information for communities on sustainable management. RAMCEA recognizes these challenges and aims to strengthen and coordinate institutions for the wise use and conservation of wetlands in the region. However, there is still much to be done to achieve the initiative's objectives as discussed by Kalanzi, (2015). RAMCEA urges member countries to support the initiative financially and technically to help it succeed.

2.12 The Nile Water Treaties

The 1929 Nile Waters Agreement was an agreement made between Great Britain, on behalf of Sudan and its East African colonies, and Egypt concerning the utilization of the Nile's waters. The purpose of the agreement was to ensure and facilitate an increase in the amount of water supplied to Egypt. One of the key provisions of the agreement was that no irrigation, power projects, or actions could be carried out on the Nile River, its branches, or the lakes from which it originates in Sudan or in countries under British administration without the prior consent of the Egyptian government, if it could affect the amount, timing, or level of water reaching Egypt according to Ferede & Abebe, (2014).

Essentially, the 1929 Nile Waters Agreement recognized Egypt's historic and natural rights to the Nile's waters, and was a correspondence between Egypt and Great Britain, acting on behalf of Sudan and its East African colonies. The agreement was later revised in 1959, but it still contained provisions that prevented the Nile Basin countries from using the waters for significant irrigation and other projects without Egypt's consent. The 1959 agreement was a bilateral agreement between Egypt and Sudan and did not include any of the other Nile riparian countries, such as Ethiopia, Uganda, Kenya, Tanzania, Rwanda, Burundi, and the Democratic Republic of Congo. The 1959 agreement divided all of the Nile's waters between the two downstream countries, with Egypt receiving 92.3% and Sudan 7.7%.

The Treaty between Egypt and Sudan gives Egypt the power to oversee the Nile's flow in the upstream countries and reject any construction projects that could harm its interests. This highlights the importance of ensuring a continuous water flow from the upstream countries to Egypt through the Nile River, which is the primary outlet for Lake Victoria. The largest lake in the Nile basin, Lake Victoria, is shared by Kenya, Uganda, and Tanzania, and its catchment area spans 184,000 km2, with Burundi and Rwanda also contributing to it. The lake obtains about 85% of its water from annual average rainfall of 1,500 mm, and the rest comes from rivers that drain the catchment area, Ferede & Abebe, (2014).

To sustain this flow, it is essential to properly manage and conserve the wetlands and rivers that contribute to the lake. For instance, the Rigathi River flowing through Nyangongo wetland joins the Kuja River as the primary river from Kisii that empties into Lake Victoria.

2.13 Legislative Framework and Strategies for Wetland Management in Kenya

Kenya has committed to conserving its wetlands through various international agreements and conventions. During colonial times, wetlands were classified as crown land and not cultivated. Following their independence in 1963, the wetlands remained under government jurisdiction, while still being accessible to the public. This control ensured the preservation of the wetlands' natural and ecological conditions, which were primarily utilized by the impoverished for collecting and irrigation purposes. To conserve wetlands and encourage their sustainable management, various national and sectoral laws were put in place. These laws encompass the Agricultural Act (Cap 318), The Environment Management and Coordination Act CAP 387, the Water Act (2016), and The Land Act, 2012. The Wildlife Conservation and Management Act 2013, The Forest Act (2016), Fisheries Act CAP 378, as well as Kenya's Vision 2030 and National Wetland Policy (2013).

2.13.1 Constitution of Kenya 2010

Kenya reached an important achievement in August 2010 with the adoption of the Constitution, especially concerning the management of land and natural resources. The Constitution serves as a guide for the creation of policies and laws, as well as the need to modify outdated regulations to align with it. Notably, the Constitution introduced principles related to land, environment, and natural resources management.

The constitution of Kenya contains clauses that highlight the significance of safeguarding wetlands and the environment in general. Article 42 of the constitution guarantees that everyone has the right to a clean and healthy environment, which encompasses the protection of wetlands as a means of water filtration. The government bears the responsibility of ensuring sustainable use and management of natural resources, encouraging public participation in environmental conservation, and putting an end to activities that endanger the environment. Moreover, Article 69 of the constitution places obligations on the State regarding environmental protection and the sustainable utilization of natural resources. Individuals are also expected to work together with the government and other organizations to safeguard and preserve the environment, as well as to promote the sustainable utilization of natural resources. The Kenya wetland policy aligns with these constitutional principles according to Kenya, (2013)

The Environmental Management and Coordination Act includes specific provisions to safeguard wetlands, as outlined in Section 42. This section prohibits any wetland-related activities without the prior approval of the Director General of NEMA and the submission of an Environmental Impact Assessment (EIA) report. The aim of requiring an EIA is to ensure that wetlands are protected, and any actions such as blocking, directing, draining, disturbing, or excavating a wetland can only be undertaken after it is established that they will not cause harm to the wetland. The Act also grants the Minister in charge of the environment the power to designate a wetland as a protected area and impose necessary restrictions through a Gazette notice to prevent environmental degradation. When making the declaration, the Minister must take into account the size of the wetland and the interests of the communities.

2.13.2 Environmental Management and Coordination Act, Cap 387

This paragraph highlights the legal framework in place to manage the environment in the country, which aims to promote sustainable development and a rational approach to environmental management. The principles established by the law apply to all sectors, including wetlands. To oversee and coordinate environmental matters, the law creates the National Environment Management Authority (NEMA) as the primary government body responsible for implementing environmental policies. Furthermore, the Environmental Management and Coordination Act provides specific provisions for the protection and conservation of wetlands, as outlined in Section 42.

This section of the Environmental Management and Coordination Act states that no activities related to wetlands are allowed without the prior approval of the Director General of NEMA and an Environmental Impact Assessment (EIA) report. The purpose of requiring an EIA is to ensure that wetlands are protected, and any activities such as blocking, directing, draining, disturbing, or excavating a wetland can only be carried out if it is determined that they will not have a negative impact on the wetland. Additionally, the Act gives the Minister responsible for the environment the power to declare a wetland a protected area and to impose necessary restrictions through a Gazette notice to prevent environmental degradation. The Minister must consider the size of the wetland and the interests of the communities when making the declaration according to Kibutu & Mwenda, (2010).

2.13.3 The Water Act, 2016

The Environmental Management and Coordination Act outlines rules for managing, conserving, controlling, and using water resources, as well as regulating the acquisition and use of water rights. Wetlands are recognized as swamps in the Act, which highlights their importance. The Act also sets guidelines for the ownership, control, and use of water resources, and advocates for an Integrated Water Resources Management (IWRM) approach to ensure the coordinated development and management of water, land, and related resources in a sustainable manner. This approach aims to balance social and economic benefits with environmental sustainability, and it takes an ecosystem-wide perspective (Ominde, (2019).

The Water Act has two key features that are applicable to wetlands. Firstly, it consolidates various functions associated with sustainable water resource management. Secondly, it provides a structure for the involvement of diverse stakeholders in water resource management. The Environmental Management and Coordination Act allows for decision-making to be carried out at the local and regional levels, which fosters involvement from a diverse group of stakeholders, such as communities and private entities.

The Water Act has provisions that offer financial support to counties through both conditional and unconditional grants to aid in the development and management of water services in marginalized or underserved regions. This financing helps in the promotion of community-level initiatives for sustainable management of water resources and research activities related to water resource management. Additionally, the Act empowers Water Resource Users (WRU) who are responsible for managing and conserving water resources and promoting citizen participation in designing and implementing water resource management initiatives throughout the country.

2.13.4 The Kenya Wetland Policy 2013

The government has developed a Wetland Policy that seeks to collaborate with relevant parties to map out wetlands across Kenya and facilitate the creation of catchment-based wetland management plans through inclusive engagement. This strategy aims to promote the sustainable utilization of wetlands, considering their ecological and socio-economic roles, for the present and future generations. Additionally, the policy highlights the government's dedication to tailoring the implementation of Ramsar guidelines to suit Kenya's specific circumstances as discussed by Olindo, (1992).

The main goal of this policy is to achieve the sustainable management and conservation of wetlands in Kenya through community involvement and the establishment of targeted programs aimed at restoring their ecological integrity. The policy outlines various objectives aimed at addressing the challenges associated with wetland management and conservation, such as:

i. To establish a system of laws and organizations that can effectively and efficiently manage and utilize wetlands in an integrated manner.
ii. The second objective is to ensure the continuation and enhancement of the benefits and roles that wetlands provide in terms of ecological diversity, preserving natural resources and their benefits, and enhancing the quality of life of the people in Kenya.
iii. To encourage stakeholders' interaction, knowledge, and public awareness
iv. To broaden the scientific understanding of Kenyan wetland ecosystems.
v. To increase institutional capability for wetlands management and protection.
vi. To support creative planning and integrated ecosystem management strategies for Kenyan wetlands management and conservation.

vii. To encourage partnerships and collaboration for the management of trans-boundary wetlands at the county, national, regional, and international levels.

2.13.5 Kenya Vision 2030

Kenya's plan for the year 2030, as outlined in Section 5.1 of its Vision 2030, prioritizes environmental conservation in accordance with Goal 7 of the Millennium Development Goals (Gok 1999). This blueprint aims for sustainable economic growth and a globally competitive Kenya by 2030. To achieve this vision, it is essential to manage wetlands sustainably, which is crucial for water purification and filtration of effluents to improve water quality for use. The social aspect of Kenya's Vision 2030 prioritizes the development of an equitable and unified society that thrives in a safe and clean environment. The plan integrates environmental management and prioritizes conservation efforts while building institutional capacity for effective environmental planning and governance. These measures aim to improve the overall management of the environment. Vision 2030 promotes an ecosystem-based approach to environmental management, as evident from its emphasis on water catchment management and mapping of land cover and land use as discussed by Odhiambo, (2014).

2.13.6 Physical and Land Use Planning Act 2019

The principal objective of this legislative measure, which is enforced by Parliament, is to govern and synchronize the physical planning and development activities undertaken within the nation. The legislation outlines that the individuals behind development projects must first acquire approval by submitting applications before proceeding with any developmental endeavors.

The Act stipulates precise regulations that must be adhered to prior to undertaking any land use activity. These guidelines dictate that physical and land use planning should promote sustainable land utilization, encourage the development of habitable communities that address human needs, and integrate the economic, social, and environmental necessities of present and future generations. Furthermore, physical and land use planning must consider the long-term optimal usage of land, conserve scarce land resources, and safeguard land that serves vital functions as asserted by Ayonga, (2022) The Act promotes environmental conservation, protection, and enhancement, and despite not explicitly mentioning wetlands, it can serve as the foundation for the conservation and management of sensitive ecosystems like wetlands by all relevant authorities to ensure the sustenance of people's livelihoods. The Act also advocates inclusive planning that takes into account the affected population's culture and heritage.

2.13.7 Land Act 2012

The Land Act aims to promote sustainable management and administration of land and resources derived from land, among other objectives. It contains provisions regulating the sustainable conservation of natural resources derived from land and measures to safeguard important ecosystems and habitats. Section 11 of the Act authorizes the National Land Commission to take action to preserve public land that threatens endemic species of flora and fauna, vital habitats or protected areas. The Commission is also responsible for identifying ecologically sensitive areas within public lands, taking appropriate action to demarcate or protect them, and preventing environmental degradation and climate change, subject to consultation with existing conservation institutions. Moreover, the Commission must create rules and regulations for the sustainable conservation of natural resources derived from land, including measures to safeguard critical ecosystems and habitats as discussed by Boone et al., (2016).

The National Land Commission Act defines the roles and responsibilities of the National Commission, which was created under Article 67 of the Constitution. One of its core mandates is to supervise and track land use planning throughout the nation. As a result, the Commission is in a strong position to enforce the implementation of the National Land Policy's provisions on land use planning and ecosystem management, including those that relate to wetlands such as Nyangongo.

2.14 Research gap

According to existing literature, wetlands provide a range of ecosystem services, such as water filtration, flood mitigation, climate regulation, and the recharge of groundwater reserves. These services improve the environment's quality and reduce the risk of harm to people and assets. Despite the strong urge to utilize wetlands responsibly, by applying ecosystem-based strategies under the sustainable development framework stated in Ramsar 2010, there has been insufficient progress in doing so.

There is significant worry that the direct exploitation of wetland resources is happening at the cost of biophysical processes, as indicated by Finlayson & Horwitz, (2015). Nevertheless, the correlation between wetland preservation and their ecosystem services is being undervalued.

The Kenyan government has established numerous tools to direct the management and conservation of wetlands. The Kenyan government has implemented the 2013 Wetland Policy, which mandates collaboration with various stakeholders to map wetland areas nationwide. The policy also aims to promote the creation and execution of catchment-based management plans using participatory methods. This demonstrates the government's intention to tailor the essential Ramsar guidelines for wetland management.

Section 42 of the EMCA Act CAP 377 also emphasizes the need to safeguard and conserve wetlands. To undertake any wetland-related activities, the Director General of NEMA's approval and an Environmental Impact Assessment (EIA) report must be obtained. Kenya's development roadmap, Vision 2030, promotes a society that enjoys equitable social development in a secure, clean environment by enhancing the overall management of the environment through institutional capacity for environmental planning. Furthermore, article 42 of the Kenyan Constitution grants every citizen the right to a clean and healthy environment, which means that wetlands must be preserved to carry out their ecological functions, such as water purification. The 2013 Kenya Wetland Policy also requires mapping of wetland areas throughout the country, the formulation of catchment-based management plans, and the use of participatory techniques in their implementation.

Although there are several documents in place that provide guidance on the sustainable use of wetland resources, controlling human activities that are not subject to EIA remains a challenge, resulting in significant impacts on these resources. However, limited research has been conducted on the impact of human activities on wetlands, leading to a lack of understanding of anthropogenic factors and their influence on these ecosystems.

The loss of wetland resources is often driven by economic or political motives, as highlighted by Dixon et al., (2021). Such activities may include complete wetland drainage or double cropping to exploit market opportunities or to meet government food security initiatives. If local knowledge and management practices have not adapted, or if communities lack experience in wetland agriculture, rapid degradation may occur, thereby undermining efforts to enforce legislation aimed at promoting the sustainable use of wetlands.

Various studies have emphasized the crucial role of monitoring and regulating human activities in wetlands to ensure the continuous provision of ecosystem services Jones et al., (2018). However, monitoring efforts have failed to keep up with the pace of wetland encroachment, leading to a gap in our understanding of the extent of encroachment, and hindering the development of effective conservation and management strategies. To address this gap, this research aims to investigate human activities in Nyangongo wetland and the drivers of encroachment. The study will involve mapping the changes in land use and land cover over time (from 1984 to 2021) in Nyangongo wetland to provide a comprehensive analysis of these changes.

2.15 Theoretical Framework

The theoretical framework used in this study is based on Garret Hardin's "tragedy of the commons" theory from 1968. Hardin's theory describes a scenario where a group of pastoralists grazed their animals on a shared field with no rules or regulations governing the use of the grazing land. In such an unrestricted regime, individuals aimed to maximize their personal gains from the communal property, with the growth in livestock serving as the only measure of individual wealth, social status, and prestige. The degradation of the grazing land due to overuse was inevitable, as there were no regulations on how the land should be utilized. The herders added as many animals as possible to the land to maximize their private gains, leading to the exceeding of the land's carrying capacity as discussed by Ostrom, (2008) This resulted in the collapse of the pastoral economy and the degradation of productive ecosystems. Hardin's theory provides a framework to analyze the degradation of natural resources caused by a lack of regulation and a focus on individual gains.

Drawing from Hardin's tragedy of the commons theory, the study area experiences a similar situation in terms of land ownership. The wetland has not been gazetted by the county government to clearly demarcate its boundaries to enhance its conservation. This has led to residents encroaching on Nyangongo wetland, a common resource due to its easy access for settlement, crop farming and other socio-economic activities.

The wetland has been categorized as a trust land, with no restriction and control by relevant authorities which has resulted to the natural resource being over-exploited and intensively used resulting to its degradation. Makalle et al. (2008) suggest that in many wetland ecosystems, an asset that is believed to be a common property resource is, in reality, owned by no one, and as a result, it is often poorly managed or neglected. This will eventually result to a tragedy whose ramifications will be felt by the whole community where they continue experiencing decline of water due to drying up of springs, loss of biodiversity such as palm for mat making and thatch grass for house construction among others.

One of the major contributing factors is via political influence which makes people feel protected for any undesirable action they undertake on resource utilization which eventually culminates to environmental degradation. This contravenes the concept of wise use. The politicians have always encouraged the local community to engage in brick making, agricultural activities as a way of alleviating poverty to hoodwink them during election time to vote for them. This has resulted to conflict of interests among the environmental managers and the water resource users who are mandated to ensure the wetland is conserved for the common benefit of the community. Insufficient financial resources to enhance resource conservation and inadequate cooperation from both the national and county governments have contributed to the acceleration of environmental degradation.

2.16 Conceptual Framework

The conceptual framework of this study aims to clarify the important relationships that reflect the current state of the wetland. As is the case with most wetlands around the world, human activities have significantly influenced and altered the Nyangongo wetland. In this particular instance, the wetland has become an alternative resource for the local community to sustain their livelihoods and combat the rising levels of poverty. Livelihoods refer to the means by which people earn a living, while poverty refers to a condition where there are limited or reduced opportunities for people to sustain their livelihoods. When faced with poverty, people may resort to overexploiting natural resources, either out of necessity or ignorance, resulting in increased environmental degradation.

In order to achieve MDG7, Kenya developed a strategy paper (2001-2004) aimed at reducing poverty and promoting economic growth, emphasizing the importance of sustainable management of natural resources like wetlands, Owuor et al., (2012) The local community relies on exploiting natural resources as a means to achieve food security, which is viewed as the first step towards reducing poverty. Unfortunately, since there are no regulations in place to limit access, the overexploitation of these scarce resources is likely to occur. The wetland is being utilized by the locals for a variety of purposes, such as brick making, farming, keeping livestock, planting eucalyptus trees, and constructing infrastructure. The activities conducted on the wetland have had a considerable impact on the wetland's functions and services, leading to a decline in critical ecosystem services that benefit the local population. To guarantee the continued benefits from the wetland, it is crucial to prioritize conservation. This can be achieved by enforcing policies that concentrate on resource management, monitoring, and conservation, and involve all parties concerned in regulating land use activities on the wetland. Encouraging collaboration among all interested parties and promoting agreed best practices will aid in revitalizing the wetland's natural resources. Thus, it is crucial to educate the local community on the importance of the wetland's ecological value so that conservation and management efforts are widely accepted. By doing so, poverty reduction among the local population can be achieved.

Safeguarding natural resources is essential to ensure equitable access to clean air and water for all individuals, irrespective of their socioeconomic status. It also serves as a form of risk mitigation against adverse events such as crop failure, market fluctuations, and natural disasters. By implementing proper conservation practices that involve community participation and enforcement of planning policies, negative impacts such as loss of biodiversity, water pollution, habitat destruction, flooding, waterborne diseases, and resource conflicts can be minimized. Conservation efforts should not result in the exclusion of local communities from resource use; to attain the intended conservation objectives, it is important to engage the local community in the entire process. This can be summarized as shown in Figure 2.3:

Conceptual Framework

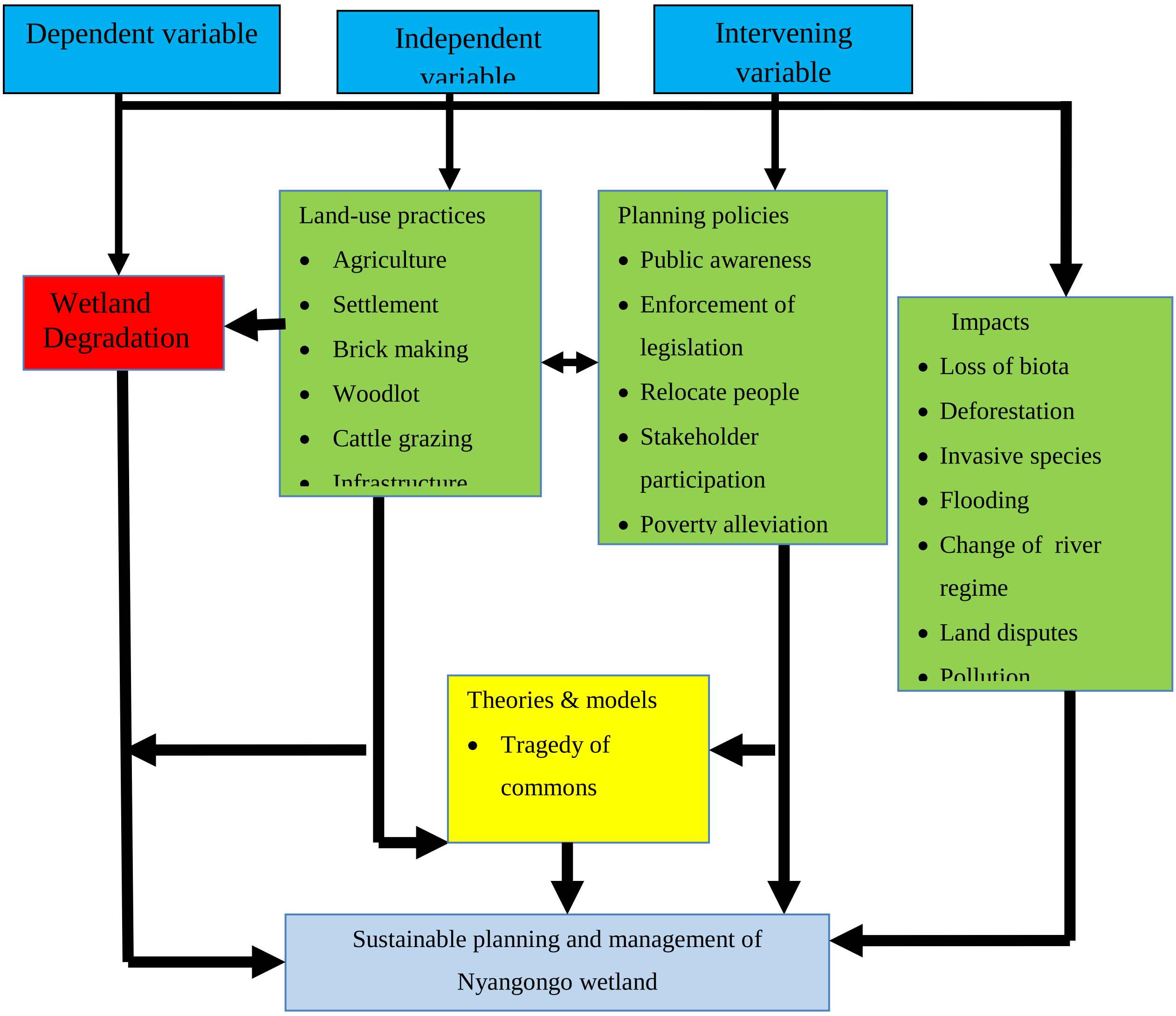

Figure 2.3: Conceptual Framework

Source: Authors' Design, 2021

2.17 Chapter Summary

This chapter focused on background information on the reviewed literature that aided on the culmination of research gap for this study. This covered various aspects such as the importance of the wetlands, distribution of wetlands, threats to wetlands and its loss, wetland management and institutional framework and the theory that resonates with the study that was conducted. This formed a basis of coming up with methodology to adopt.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The current section provides an outline of the methodology used in the study. It commences by discussing the study location, the research design, and methodology employed in the study area, followed by a description of the sampling technique, data collection process, and analysis and interpretation methods used.

3.2 Study Area Description

The focus of this chapter is on the Nyangongo wetland, which is located about 10 kilometers south of Keumbu market. The wetland spans 825 hectares and is situated at GPS coordinates 704,513.91 meters East and 9910989.53 meters South. It is crossed by several streams and rivers, with Rigathi river being the primary one. Previously, the wetland was categorized as a trust land registered under Kisii County Plot No. 770. However, according to the Kenya Constitution of 2010 and the Community Land Act of 2016, all trust lands must now be registered under the County Government. The legislation specifies that in cases where communities fail to register their lands, it is the responsibility of the County Government to initiate the registration of community land in collaboration with the participation of the local individuals. This is as per to the Customary Land Tenure which gives the community members the right to utilize the land free of charge with their family and dependents.

This has given a leeway to the local communities who have invaded the wetland and sub-divided it among themselves, though they do not possess ownership documents. The wetland encroachers are mainly the local communities who have resorted to settling on the wetland and some engage in day time activities such as brick making, grazing and subsistence farming. Encroachment has been a perpetual phenomenon due to continuous population increase resulting to land fragmentation. The increasing human populace lack other alternatives to sustain their livelihoods hence they forcefully invade the wetland even with the restriction of the local administrative organs and WRUA who are mandated to ensure the wetland is protected. However, some invaders own land outside the wetland but only engage on day time activities like brick making to generate some income as a supplement to their other sources.

Land ownership has therefore been a thorny issue that has perpetually resulted into conflicts between communities of Bobasi in Gucha and Kisii in Kisii Central. This is as result of the land tenure system which does not allow land ownership to the majority of the locals especially women who are not entitled to own land. Only 35% of the total land mass in Kisii has been titled “Kisii ICDP, 2019” as discussed by Ondieki et al., (2022).

There is a scarcity of indications that suggest the swamp remains in its natural state during the dry season, as the locals tend to drain off the water to make more space for land-based activities such as crop cultivation.

The Nyaribari side appears more prolific and established with agricultural activities with a fairly prominent stream than the Bobasi side which provides livestock watering points. Farmers whose parcels adjoined the wetland had extended their plots running through the swamp area which then contravenes ideal use of this resource.

A couple of problems are prevalent in the area particularly with respect to water declining in the streams and exhibiting low discharges as a result of extensive planting of eucalyptus trees along river banks thus resulting to low stream flows and river Gucha in particular which acts as the main tributary that drains surface flows to the Lake Victoria.

Figure 3.1 on the next page Shows the Location of Nyangongo Wetland.

Figure 1

Figure 2

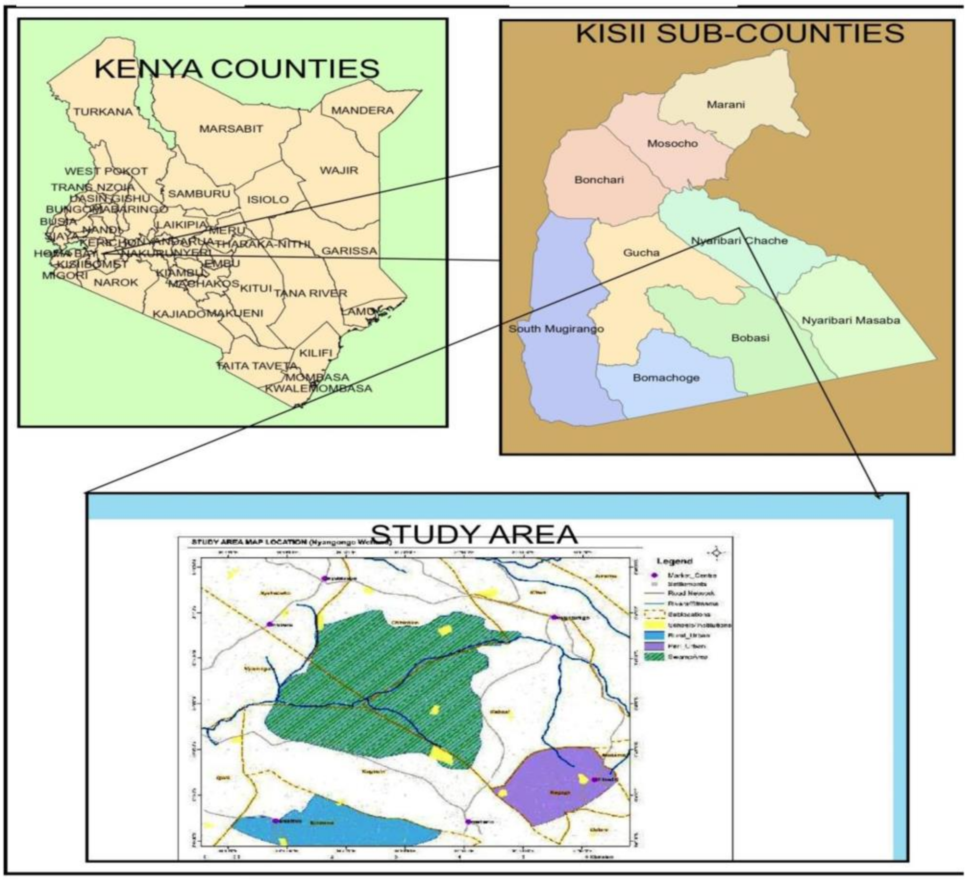

Figure 3

Figure 3.1: Map of Kenya Showing all counties (figure 1), Map of Kisii county showing sub-county administrative units (figure 2) and Map of study area indicating Nyangongo wetland in Nyaribari chache sub-county (figure 3)

Source: Google Map and Survey of Kenya-Kisii County

3.3 Population profile of the Area

The study area is experiencing a fast-growing human population, which is the demographic profile. The area where the wetland is located has a population density of 919 individuals per square kilometer, and the average landholding ranges from 0.2 hectares to 2.1 hectares, according to the Kisii County Integrated Development Plan of 2018. This implies that as the population in the area grows, the amount of land available for each individual is likely to decrease, making it more difficult to maintain their livelihoods. This puts additional pressure on the natural resources as people living near rivers and other bodies of water engage in activities that are not sustainable, leading to a decline in the ecosystem's resilience. This leads to development of social infrastructures on wetland area as the only remaining open space to service and accommodate the human population.

3.4 Drainage of the Study Area

The main river that drains the wetland is Rigathi River, which is also the major tributary of Kuja River. It is dominated by seasonal streams which traverse through the wetland where locals obtain water for domestic purposes.

3.5 Climatic Conditions and Soils

The chapter's study area has a highland equatorial climate with a bimodal rainfall pattern, with long rains from March to May and short rains from October to December. The rainfall ranges from 1500mm to 2200mm, and January and July are relatively dry. The mean annual temperature ranges from 16ºC to 22ºC, which is suitable for growing crops like tea, coffee, pyrethrum, maize, beans, and bananas, as well as dairy farming. According to the Kenya Meteorological Department's 2016 report, the weather conditions in the study area are favorable for these agricultural activities.

3.6 Geology and soils

Various types of soil are found in the region, including red volcanic soils (nitisols), red loam soils, sandy soils, and clay soils that have poor drainage (phaezems). In addition, black cotton soils (vertisols) and organic peat soils are present in the low-lying areas, as noted in the Kisii County Integrated Development Plan (CIDP) of 2018.

3.7 Vegetation

The plant cover in an area is influenced by various factors such as soil type, climate, and living organisms. The optimal growth of a plant is determined by several factors, including the pH of the soil, water availability, and other environmental factors. Many plants thrive in soils that are slightly alkaline or neutral, and the amount of water in the area also affects plant growth.

Nyangongo wetland is endowed with a variety of vegetation both indigenous and exotic. The rare palm tree species which exists in patches on the wetland used to be a dominant plant in 1960s and 1970s before encroachment and was used for handcraft making. The other few noticeable vegetation is sedge grass, petunia grass and a few stamps of acacia which portrays some little evidence of swamp conditions. There are also widespread stands of Eucalyptus on the wetland stretching to upland areas, in open farms, along the stream banks with no riparian reserves.

Plate 3.1: Shows palm and cattail grass on the wetland; at the background is a church coupled with brick making activities. (Photo by the author, 09/03/2021).

3.8 Economic Activities

The primary economic activities in the region are centered around agriculture, including tea, sugarcane, maize, banana, cassava, beans, and vegetables. Small eucalyptus plantations are also prevalent and have a ready market in tea factories and Timsales Company as fuel. The locals engage in small-scale dairy and poultry farming. However, some crops such as sugarcane, cassava, and yams grown in the wetland consume large amounts of water and do not return nutrients to the system as effectively as papyrus, leading to an imbalance in the ecosystem. The locals especially the youth also engage in boda boda business and brick making which helps them to cushion their economic needs since most of the available land has been fragmented to uneconomic portions and the rate of unemployment and underemployment is prevalent in this area.

3.9 Nature of Data and Their sources

During the study different types of data were used and consulted from different sources as detailed below;

3.9.1 Primary Data source

This data was solicited using pre-tested household questionnaires that was administered to the male or female head of the household, Key informants such NEMA Director, Kisii sub-county environment officers, Agricultural officers who liaise with households to provide extension services, sub-county forest officer, director of water and sanitation, officer from the water resource management authority, and officers from the water resource users association. The data that were collected from key informants delved into the drivers that have influenced wetland conversion, some of the environmental challenges that have resulted to wetland degradation in conjunction with the measures put in place to address them, how often they monitor the human activities conducted in and around the wetland, list any challenges they encounter when they enforce legislation on environmental conservation and whether they receive any support from both the county and national government to facilitate wetland management and conservation. The data was gathered March 2021 whereby senior officers drawn from each department were interviewed. This was preferred as the junior officers were perceived to hide some pertinent information for fear of being reprimanded.

3.9.2 Secondary Data Source

The researcher obtained secondary data for the study by examining previously recorded sources such as academic papers, thesis, and satellite imagery that pertains to the study area and topic. The Global Land Cover Facility (GLCF) website was utilized to download Landsat imagery from 1984, 1994, 2004, and 2021, which were selected for their minimal cloud cover. The primary objective of the research was to examine the patterns of land use changes from 1984 to 2021. A list of the satellite images used in the analysis is presented in Table 3.1.

Table 3.1: 1984-2021 Spatial Datasets Summary used in the Study

Image	Resolution	Date	Path/Row	Source
Landsat 5 TM	30M	1984	170/060	GLCF
Landsat 5 TM	30M	1994	170/060	GLCF
Landsat 7 ETM+	30M	2004	170/060	GLCF
Landsat ETM+	30M	2021	170/060	GLCF

Source: GLCF

For the first objective information obtained from Landsat images coupled with the one gathered through household survey particularly on human activities conducted on the wetland, factors influencing wetland conversion was used for further analysis to generate results that helped arrive at final conclusions and recommend viable interventions for the study.

3.10 Research Design

Abbott & McKinney, (2013) defines research design as a scheme or blueprint that is employed to find solutions to research problems, while Mitchell & Jolley, (1988) describes it as a roadmap for collecting, evaluating, and interpreting data. This study utilized a mixed-methods approach that integrates qualitative and quantitative methods to collect both primary and secondary data. This approach provides a more comprehensive understanding of the research questions. The research utilized socio-economic data and multispectral satellite imagery to analyze and measure the spatial extent of land use and land cover changes.

3.11 Study Population

Abbott & McKinney (2013) explains that target population refers to the specific group of individuals or objects that the researcher intends to study and whose characteristics are of interest to the research. A larger sample size is required when the target population is diverse and contains significant differences. This enables the study to capture the population's variability and enhances the reliability of the findings. The study targeted all household heads/alternative aged 18 years and above residing at a distance of proximity area of 1-4km from the wetland. This was informed by literature via the *distance decay theory* which describes the effect of distance on spatial interactions between two separate locations. Time and distance imply that there is diminishing influence of the phenomenon or activity resulting to less interaction between distance places. This implies in this scenario that there is diminishing accessibility to the wetland to obtain wetland products as the distance increases resulting in the decrease of derivable products to sustain livelihoods. This is also corroborated by research by Guthiga & Mburu, (2006) which avers that propensity of resource use in terms of beneficiaries decline drastically beyond the edge of the natural resource. The residents in these areas obtain resources from the wetland such as water for domestic use, bricks for construction, engage on agricultural activities on the wetland among others. Hence the distance was considered appropriate to conduct the study. The distance falls within the following administrative units; Kabosi, Chirichiro, Kegochi, Nyakondiere, Nyakebako and Nyamagwa sub-locations. According to 2019 census these areas comprise around 2,449 households. The data collection was conducted in the Month of March 2021.

3.11.1 Sample Size

The Yamane 1967 fomula as explained by Israel, (1992) was used to get the sample size and it is as follows:

$$n=\frac{N}{1+N(e)^2}$$

Where n = sample size

N= target population size

e= level of precision (sampling error)

In this study the population size is N=2,449 household heads sampling error = 5%

Therefore

Sample size $n=\frac{2,449}{1+2,449(0.05)^2}$

$$=\frac{2,449}{1+2,449(0.0025)}$$

$$=\frac{2,449}{9.7825}$$

= 251 household heads

A total of 251 questionnaires were completed and used for data analysis. The distribution of respondents in each sub-location is depicted in Table 3.2.

Table 3.2: Number of Respondents Interviewed per Sub-location

Sub-location	No. of Households	Sampled Households	Percentage (%)
Chirichiro	710	60	24.0
Kabosi	430	45	18.0
Nyamagwa	388	40	16.0
Nyakebako	201	28	11.1
Nyakondiere	340	40	16.0
Kegochi	380	38	15.1
	2,449	251	10.2

Source; Author, 2021

3.12 Sampling Procedures.

The following sampling procedures were employed to select the respondents:

3.12.1 Stratified Random Sampling

The study utilized a sampling method to select respondents from the targeted population in the study area, specifically within a four-kilometer radius from the boundary of Nyangongo wetland. Households located beyond the specified radius were excluded. The study area was comprised of three locations that were Purposively selected as they fall within the selected distance for data collection. These were further subdivided into six clusters, or sub-locations, which were again purposively selected as they were within the selected locations and were deemed suitable for clustering. Proportionate stratified random sampling was employed to determine the appropriate number of households to be included in the survey based on the proportion of each sub-location to the total number of households in the study area. Sampling started from the location level and down to the sub-locations and finally to the individual households. (Table 3.2)

Households were used as sampling units and household heads or their alternative were targeted to provide the required information. The data was collected by administering questionaries by the researcher with the help of the research assistant to the targeted respondents. This was achieved by picking the first respondent randomly in each stratum and then randomly pick the next respondent and the same process was repeated until all the targeted population was exhausted to achieve the total sample size of 251 samples from all the 6 sub-locations.

Overall, a total of three (3) locations, six (6) sub-locations, two fifty-one (251) households were considered representative enough for the socio-economic survey to be conducted in this research.

3.12.2 Purposive Sampling

The study employed this method to select key informants with relevant information on land uses, management, monitoring and conservation issues in the study area particularly government entities in relation with wetland management. The process of selecting key informants was based on the relevance and availability of respondents who meet the required selection criteria Abbott & McKinney, (2013). Key informants in this study were identified as institutions such as NEMA, Ministry of Environment-Kisii County, Forestry department, Ministry of agriculture, Water Resource Management Authority (WRMA), and Water and Sanitation department.

3.13 Data Collection instruments

The study used six collection instruments;

3.13.1 Questionnaires

The questionnaires contained several questions on the socio-economic activities the local community were engaged with on the wetland, identify some of the drivers that encourage locals to engage on wetland conversion, the type of crops they plant on their farms, whether they were aware of any wetland policies/guidelines on conservation of the wetland and whether they follow those guidelines for conservation of the wetland. The respondents were given a structured survey, Appendix I, that included both open-ended and closed-ended questions Abbott, & McKinney, (2013).

3.13.2 Key Informant Interview guide

It was important to gather input from the key informants regarding several matters including the causes of wetland encroachment, the measures implemented to mitigate challenges related to wetland degradation, and the adequacy of funding for wetland management. This direct engagement helped to obtain reliable and valid information in the form of verbal responses from one or more respondents Abbott & McKinney, (2013).

3.13.3 Focus Group Discussions (FDG) guide

Focused group discussions (FGD) were also conducted as a follow-up to the individual interactions in interviews Abbott & McKinney, (2013). FGD were conducted at the community level mainly with people who depend largely on the wetland.

The study conducted two focus group discussions that comprised 8-12 male and female participants. The individuals who took part in the focus group discussions included the local farmers, brick makers, and members of the Chirichiro Water Resource Users Association (WRUA) who were well versed with the study area. The main objective of these discussions was to gather details about the usage of the wetland. The farmers and brick makers often interact with the wetland almost on a daily basis in their pursuit of utilizing the wetland resources to sustain their livelihoods and augment their sources of income. During the focus group discussions, several topics were explored and recorded. These included identifying the reasons why people encroach on the wetland, the types of activities conducted on the wetland, the crops grown on the wetland, whether organic or inorganic fertilizers were used, the current size and vegetation cover of the wetland compared to 20 years ago, and trends in wetland use over the past 30 years.

3.13.4 Observation checklist

A checklist for observation, as provided in Appendix IV, was utilized by the researcher as a means of gathering data to corroborate the information provided by the participants. This was used to record different parameters such as water quality (appearance), type of crops cultivated, approximate quantity of water at different springs and different tree species (palm trees, acacia, solanum).

3.13.5 Photography

Photographs were considered as a precise and trustworthy tool for data collection as they depicted the real situation on the ground. They were used to confirm the results obtained from other sources of data collection, to depict the form and type of land use activities. Photography was helpful in capturing observable features, which aided in explaining the objectives of the study. This was an effective way of recording the physical environment and land use practices as depicted on the ground.

3.13.6 Satellite imagery

Satellite data from LANDSAT images corroborated with google earth images were used. This information aided in determining the changes over space and time of the land use and land cover of the area under investigation and facilitated the evaluation of the effects of wetland use. The data was utilized to create maps that depict the past land use and land cover.

3.14 Materials and Software Used

Various materials and software were utilized to gather, systematize, and interpret data for the study. For instance, ERDAS imagine 9.1 software was used for geo-referencing, compositing and classifying land use categories of the study area. It was also used for delineating and clipping the study area, and for creating layouts for the final maps. In addition, Preliminary Index Diagrams (P.I.D) were obtained from the Survey of Kenya- Kisii offices to show the wetland boundary. These were adjoined to come up with the area covered by the wetland. This was then used to abstract the wetland data used for analysis from the satellite images that were downloaded referencing the particular periods identified for the study.

Microsoft Excel was utilized to create visual aids such as bar graphs, pie charts, and tables to present and organize data collected through qualitative means, such as from questionnaires.

ENVI 4.1 Software was employed in this study to analyze the changes in land use that occurred during the study period. The software utilizes image differencing, which involves subtracting the pixel digital values of the images taken at different times. This method is commonly used in change detection due to its high accuracy, ease of computation, and interpretability, and was therefore chosen for this study.

3.15 Data Processing and Analysis

The study utilized Landsat images with a resolution of 30 meters, which had already been corrected and were the most up-to-date and reliable in change detection and trend analysis. The object-oriented classification method was applied to classify the different types of land use in the study area. Digital Image Processing (DIP) techniques was used to analyze images, creating maps that display the changes in land use and land cover that occurred over 37 years.

Since there were no clouds present in the catchment area of the study site, atmospheric correction was not necessary for the images. This helped to clearly identify different areas of interest as; Dark grey areas were interpreted as swampy, wetland types and waterlogged areas; Light grey areas constitute other vegetation types such as grasslands and scattered tree shrubs appearing within the wetland area. Vegetation cover around the swamp as portrayed in terms of area coverage in subsequent years and light pockets represent cultivated farms on the wetland area. This procedure was also supported by a Google Earth image of the study area, which was deemed up-to-date and ensured that the classified land use class was an accurate reflection of the actual conditions on the ground. This was also complemented by the prior knowledge of the area by the research that made verification of different classes an easy task.

The socio-economic data gathered through questionnaires were analyzed using Statistical Package for Social Science (SPSS) Version 20. To assess the human activities conducted on the wetland, descriptive statistics analysis was employed.

To establish a correlation between human activities and the wetland ecosystem, multiple regression analysis was applied to determine the extent of the relationship between the variables. The coded data in SPSS on human activities that represented the X variable was statistically compared with the wetland area data (Y variable) in Table 4.4 for all the entire study period from 1984 to 2021. This helped to infer how human activities have impacted on the wetland ecosystem.

Regression Equation

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon \text{ ....Eq 3.1}$$

Where:

Y Represents wetland

X_1 Represents crop farming

X_2 Represents thatch grass and fiber

X_3 Represents wood fuel

X_4 Represents brick making

β_{0+} Represents a constant

From $\beta_{1,}$ to β_9 represents the regression model's coefficients

Key informant interviews and Focus Group Discussions (FGD) data were analyzed in an inductive manner, which involved identifying themes and quotations to provide relevant information on wetland utilization, emerging issues, and conservation challenges. The responses provided by the respondents on issues such as causes of wetland encroachment and the impacts of wetland degradation were summarized and were used as a reference in this analysis Elo & Kyngäs, (2008)

3.15.1 Geo-Referencing

This is assigning the ground coordinates to the map/image. Geo-referencing is done to each and every band of each image: 1984, 1994, 2004 and 2021. The images were projected to WGS_1984_UTM_Zone_36S.

3.15.3 Clipping

This is the process of resizing an image/map to the required size that matches the area of interest. It is done to limit the map to only the desired portion of study by using known coordinates of the required study area. Sub setting was done to all the images using ARCGIS 10.1 using a shapefile representing the research area. The boundary of the wetland overlaid on the images using the same coordinates to ensure that both the images have the same areal content. The shape file that was used to divide the image into smaller parts was derived from the boundaries of the neighboring areas that surround the wetland. This was achieved by use of P.I. Ds obtained from survey of Kenya- Kisii County Offices. Sub-setting was done to the image bands, from band 1 to band 7, using the geographical coordinates, after which the bands are given a specific projection. The coordinates used to subset the images are: -

Minimum X coordinate: 703380   Minimum Y coordinate: -86430

Maximum X coordinate: 706890   Maximum Y coordinate: -88680

3.15.4 Compositing the Image

Bands) of each image to come up with a 24-bit color composite. This involves merging three bands (green, red and infrared composite layer. All the seven bands of each Landsat image for 1984, 1994, 2004 and 2021 were combined together to produce a multispectral image (colored) of each year since the bands are panchromatic (black and white) when they are downloaded.

3.16 Classification Scheme

The researcher conducted field excursions and utilized Google map to enhance verification to able to develop a classification scheme for analyzing the land cover features surrounding the wetland in the study area. The classification scheme was broad in nature, identifying the different portions of land cover in the image and comparing them to Google map to determine the various types of land use and land cover. Those classes identified and used for this study were; Wetland area, Vegetation, Farmland and Built-up areas.

Table 3.3: Description of LULC Classes

LULC Class	Description of LULC class
Wetland Area	These refer to regions where the water level remains either permanently or temporarily close to the land surface and is covered by vegetation such as cattail grass, sedges, palms or herbaceous plants.
Farmland	These are areas used for rain fed agriculture mainly for mixed cultivation or mono cropping. Several typical crops cultivated in the area include sugarcane, maize, bananas, tea, cassava, and finger millet among others that were sighted during the study.
Vegetation	Areas covered by scattered shrubs, trees and grasslands along ridges and plain areas of the study area.
Built-up area	These are areas comprising of residential buildings, schools, roads, bridges and other man-made structures.

Source: Field survey 2021

3.16.1 Classification

In this research, the approach of supervised classification was utilized to interpret the different land cover types by assigning each pixel to a specific category. The technique of per-pixel supervised classification groups pixels of the satellite image having the same or similar spectral reflectance characteristics into distinct information categories, as explained by Campbell (2002).

3.16.2 Supervised Classification

Initially, the study area was defined and divided into land cover classes, which were then used to create training sites for each class using on-screen digitization of color composite of the image. This required prior knowledge of the study area to provide the computer with unique training classes. The training sites were defined as polygons in the form of a raster image. Maximum likelihood classifier algorithm classification was used in this study, as it is a widely used method in remote sensing image data analysis according to Richards (1995). The study area was surveyed using a Google Earth image to ensure accurate identification and separation of various land cover classes. In order to enhance the classification process, any pixels that belonged to adjacent land covers were excluded. Additionally, training polygons that had unclear spectral signatures were discarded and new ones were created based on visual analysis of the study area on both Google Maps and the image itself. The maximum likelihood algorithm was then re-run using these refined training samples. The resulting land cover classes included vegetation, farmland, built-up areas, and wetlands.

3.16.3 Signature Editor

After digitizing the training site areas, the next step was to create statistical descriptions of each information class.

To begin the analysis, training samples with the same reflectance values were collected and saved using the signature editor tool. These signatures were used to classify the satellite images into vegetation, farmland, built-up area, and wetland. The tool for the area of interest was used to collect digitized polygons of each sampled pixel, which were then classified in the signature editor. The purpose of analyzing the images was to identify and measure various land use types and map changes in land-use classes.

The process, from data acquisition to the production of LULC detection maps, is summarized in the figure 3.3.

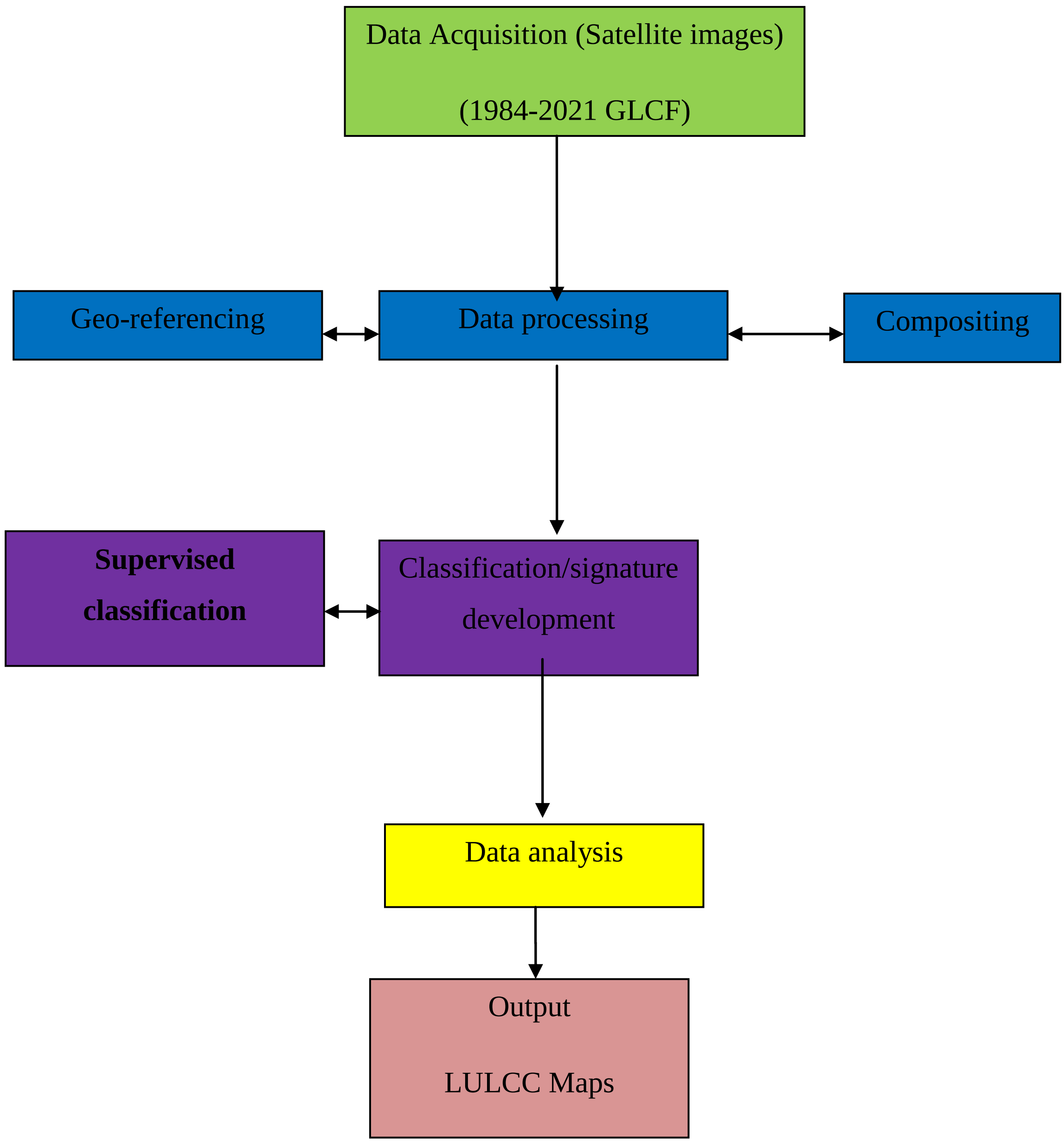

Figure 3.3 Flow Chart on satellite data acquisition, classification and analysis

Source: Researcher's Design

3.17 Spatial- Temporal LULC Change Detection

In order to study the changes in Land Use and Land Cover (LULC) between 1984 and 2021, the researcher performed a change detection analysis, which included analyzing the magnitude, pace, and evolution of the changes over time. The researcher utilized the method recommended by Jiang et al. (2008) to ensure accurate and reliable results. Effective change detection yielded valuable insights into the modifications in LULC that occurred during the study period.

1) Area change and change rate

2) Spatial distribution of changed types

3) Accuracy assessment of change detection results.

3.18 Post-Classification Comparison

Comprehensive maps indicating the land use and land cover (LULC) for the years 1984, 1994, 2004, and 2021 were created using digital classification via Supervised Maximum Likelihood Classification. This process was followed by post-classification editing, which involved comparing the newly generated maps with previously available maps. Any changes were then analyzed and presented visually through graphs.

3.19 Ground Truthing and Accuracy Assessment

Obtaining reference data through ground truthing, as outlined by Lillsand and Kiefer (2006), is crucial in accurately interpreting, classifying, and verifying remotely sensed data. The process of verifying the precision of land use/cover classifications involves checking them against the real-world conditions on the ground. In this particular study, high-resolution images from Google Earth were utilized to identify the different land cover types present in the research area. Moreover, multiple visits to the actual sites were made to validate the existence and specific type of land use cover, and photographic and GPS data were gathered to facilitate the analysis of satellite images. The accuracy of the land use/cover classification was evaluated by employing

Ground Control Points that were obtained through GPS field surveys. The error matrix method was used to compare the agreement between predicted and independently observed classes to determine if the output map met certain predetermined classification accuracy criteria.

The procedure for appraising accuracy involves measuring overall accuracy, producer's accuracy, user's accuracy, and Kappa coefficient, as outlined in Lu et al.'s (2004) work.

To perform accuracy assessment, sampling tools in ERDAS Imagine 9.1 were used to generate accuracy assessment points in a stratified random format. A minimum of 85 points were selected for each land use type, taking into consideration literature that recommends selecting between 50 to 200 points per site for accuracy assessment.

3.20 Preparation of Change Matrices

The Change Matrix displays the alterations of land use/land cover patterns to other LULC patterns. To generate the change matrices for the periods of 1984 to 1994, 1994 to 2004, and 2004 to 2021, the UNION overlay analysis was utilized within the ArcGIS platform. Subsequently, these matrices were tabulated in Microsoft Excel. This technique for change detection analyses was implemented, similar to the approach used by Richards & Richards, (2022)

3.21 Validity and Reliability of Research Instrument

According to M. Mitchell & Jolley, (1988), research instruments must be created with clear and unambiguous questions to ensure their validity. A pilot study was conducted prior to the data collection in this research to verify the accuracy of the instruments. The LANDSAT images that were utilized in the study had a satisfactory resolution of 30 meters, which made them ideal for the study. These images were obtained from the

LANDSAT satellite, which has been delivering high-quality images since the 1980s, thus providing images for the entire research period. The operational definitions of the study variables are presented in the table below.

3.22 Data presentation

Upon completion of data collection and entry, the analyzed data was presented in form of pi-chart, graphs, pictures, tables, maps and narrative report writing. This allowed for easy interpretation and understanding of the report findings.

Table 3.4: Research Matrix

NO	OBJECTIVE	NATURE OF DATA	DATA SOURCE	VARIABLES	METHOD OF DATA ANALYSIS
1	To establish spatial-temporal changes of Nyangongo Wetland between 1984-2021	Secondary data	Satellite images, Google Map.	Wetland Vegetation Farmland Built-up area	Trend analysis using Arc GIS 10.2, ERDAS Imagine and ENVI 4.1
2.	To determine human activities carried out on Nyangongo wetland	Primary data	Household Questionnaires, FGD, Field observations, photographs	Grazing Wood fuel Thatch grass Water Hunting Medicinal plants	Descriptive statistics using SPSS Version 25
3	To find out the causes influencing human encroachment on Nyangongo wetland	Primary data	Household Questionnaires, FGD, KII	Unemployment Demand on agricultural products Decline of agricultural land	Descriptive statistics using SPSS Version 25

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter deals with presentation of the study findings as follows.

4.2 Demographic and Socio-Economic Characteristics of Respondents

The following attributes define the respondents interviewed in this study:

4.2.1 Distribution of Respondents by Gender

Table 4.2 displays the gender distribution of the respondents, with females comprising two-thirds of the sample and males one-third.

Table 4.2: Gender of Respondents

Gender	Frequency	Percentage
Male	150	60
Female	101	40
Total	**251**	**100**

4.2.2 Distribution of Respondents by Age

Most of the respondents were aged between 45 and 55 years as can be seen in Figure 4.1.

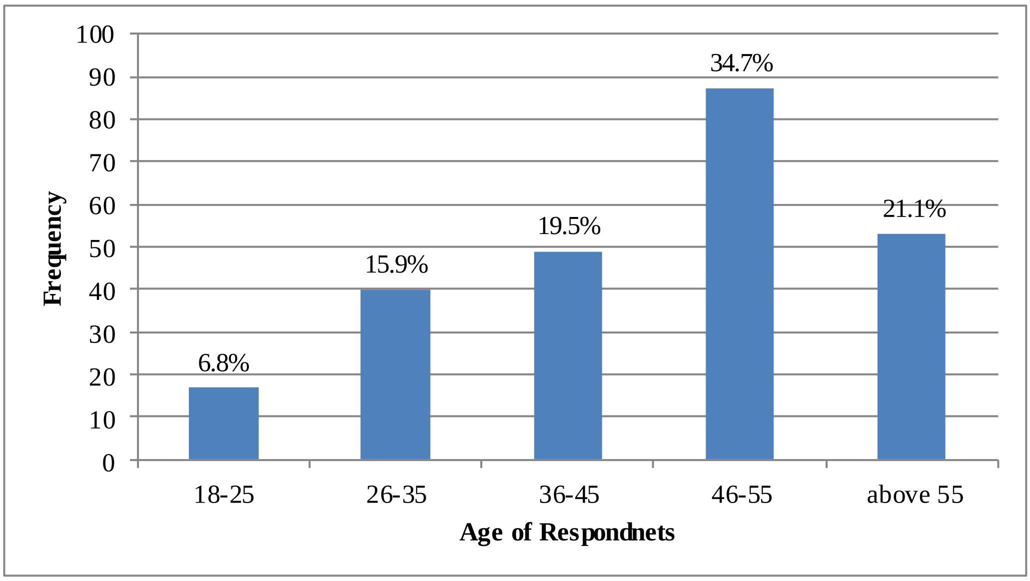

Figure 4.1 Age of Respondents

Source: Author's field data (2021)

4.2.3 Marital Status of Respondents

Majority of the respondents (82.7%) were married as can be seen in Figure 4.2.

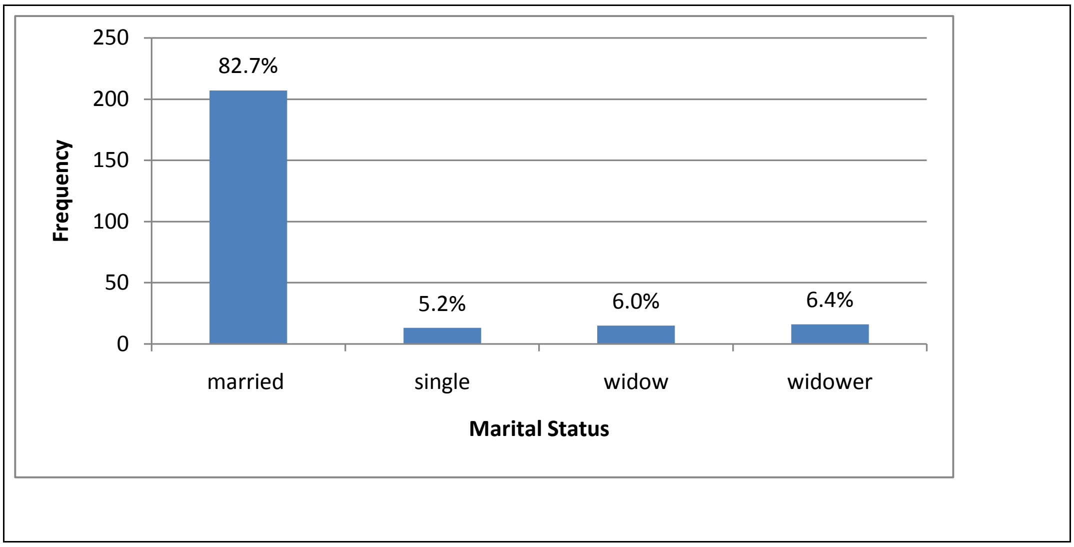

Figure 4.2: Respondents Marital Status

Source: Author's field data (2021)

As shown from the Figure 4.2 above, those who are single represent 5.2%, Widowed 6.0% and Widower 6.4% of the respondents interviewed 4.2.4 Education Level of the Respondents.

4.2.4 Education Level of the Respondents

With respect to education, all respondents were educated but up to different levels as can be seen in Figure 4.3. Majority had primary education while an almost equal proportion had secondary education. Only 21% of the respondents had attained tertiary education level.

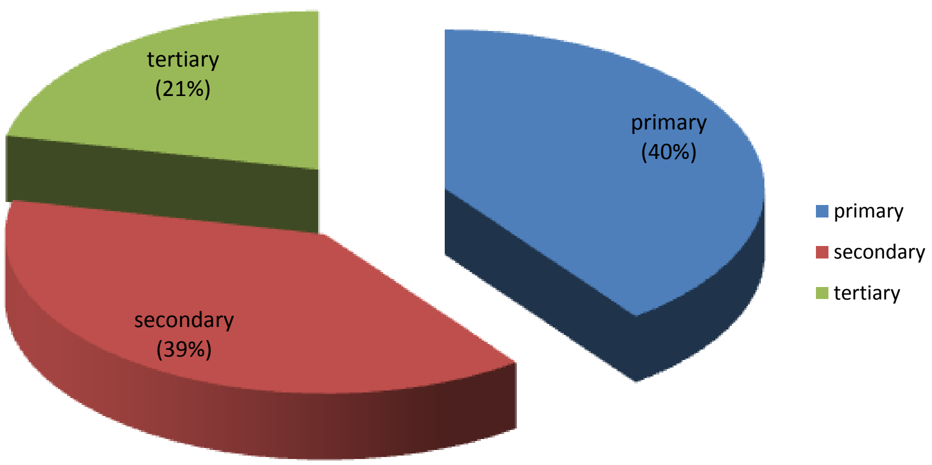

Figure 4.3 Education Levels of Respondents

Source: Author’s field data (2021)

4.2.5 Income Level of Respondents

The objective of the researcher was to identify the Monthly revenue streams of the respondents. This was vital as it helped ascertain financial status of the locals. The results are shown in Figure 4.4.

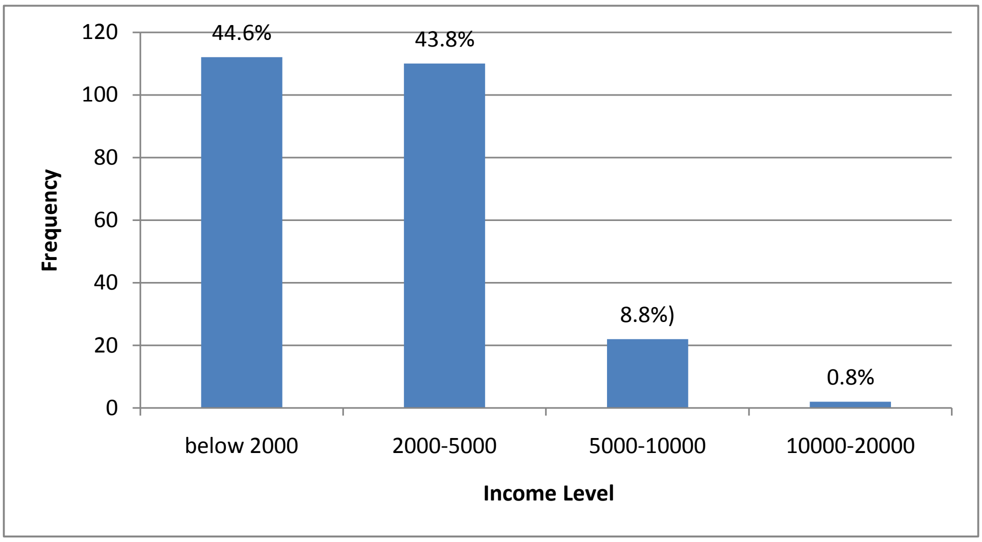

Figure 4.4 Income Level of Respondents

Source: Author's field data (2021)

As it can be seen from the Figure 4.4, most of the respondent's gross income is below KES 2000 which stands at 44.6% followed closely by those whose monthly earnings is between KES 2000- 5000 representing 43.8%, KES5000-10000 at 8.8% and the least are those who earn more than KES10000 a month representing 0.8%). Individual income levels and personal needs and requirements will reflect on livelihood sustainability as per to the current economic situation. These findings corroborate what is depicted on Table 4.3 which exhibits low land ownership by the locals' hence households resort to other economic activities which may be unsustainable to the environment. This unprecedented pressure results in wetland encroachment for livelihood opportunities leading to shrinkage of wetland thus emasculating its functionality. Unsustainable use of wetland resources can lead to a reduction in their net benefits to residents, potentially resulting in reduced long-term income. Additionally, as household size increases but income from wetland use remains constant, when land pressure is intense, households experience a greater challenge in fulfilling their fundamental necessities. This suggests that increased consumption patterns can lead to greater land intensification and further degradation.

4.2.6 Land Size

The researcher sought to ascertain land size of different respondents. This was to help determine the ranges of land sizes the locals utilize in the study area to sustain their needs. The findings are presented in Table 4.3 below.

Table 4.3: Land Holdings

Plot size (ha)	Frequency	Percentage
0.5	38	15.1
1.0	45	17.9
1.5	38	15.1
2.0	50	19.9
2.5	21	8.4
2.6- 4	27	10.8
>5	1	0.4
None	31	12.4
Total	**251**	**100**

Source: Author’s field data (2021)

From the study findings 17.9% respondents own 1 ha of land, 15.1% own 1.5 ha, 19.9% own 2 ha and the number keep decreasing as the size of land increases.

4.3 To assess the spatial- temporal changes of Nyangongo Wetland between 1984-2021

This objective sought to determine Land use/cover change in the study area for a period of 37 years. This was accomplished through classification of downloaded Landsat images of the study area covering that particular period.

4.3.1 Land use/ Land cover in 1984

In 1984, vegetation had the highest coverage of the total area with 609.07 ha (73.8%). Other land uses such as farmland, wetland, and built-up area also covered a considerable portion of the area, with farmland covering 135.65 ha (16.4%), wetland covering 72.85 ha (8.8%) and built-up area covering 7.65 ha (0.9%). Among all land uses, built-up area had the smallest coverage. These formed the baseline that was used as a reference point for detecting subsequent changes over time. The thematic map in Figure 4.5 supports these findings.

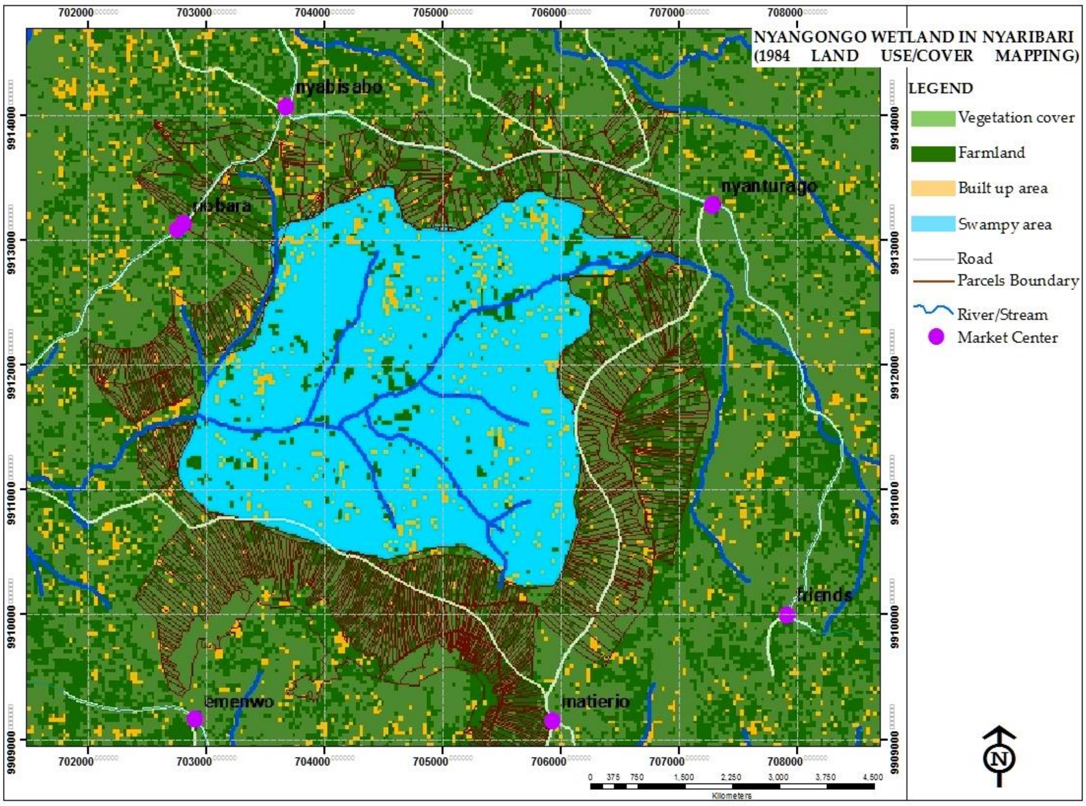

Figure 4.5 Land Cover Classification for Nyangongo Wetland 1984

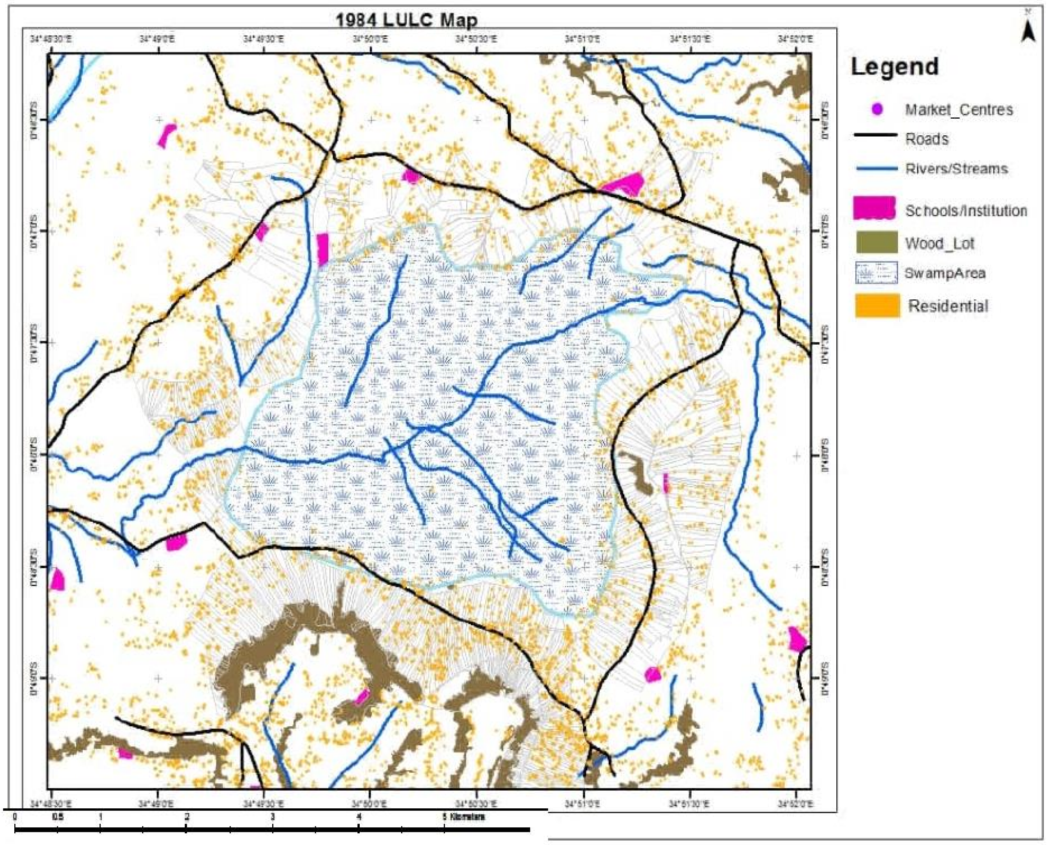

Figure 4.6 Land use Map for the Study area in 1984

Figure 4.6 above illustrates the adjacent land use practices and their likely impact on wetland functionality. The wetland environs were assessed to decipher how the prevailing human activities in the watershed such as cultivation agriculture, growth of eucalyptus and rivers draining the catchment area will help in supporting of the results obtained after image classification.

4.3.2 Land use Land Cover in 1994

After a decade in 1994, the area under vegetation cover which was 496.35 ha (60.15%), had the largest coverage of the total area. This indicated a reduction of 18.6% from the coverage area in 1984. Wetland, farmland and built-up area constituted 148.68 ha (18.01%), 96.39 ha (11.68%) and 83.8 ha (10.15%) of the total land area in 1994 respectively. When compared with that of 1984 LULC, it can be deduced that farmland area had decreased by 28.3%, Wetland area increased by 51.0 % but built-up area which represents remaining area of the wetland had increased by 76.15ha(90.9%).

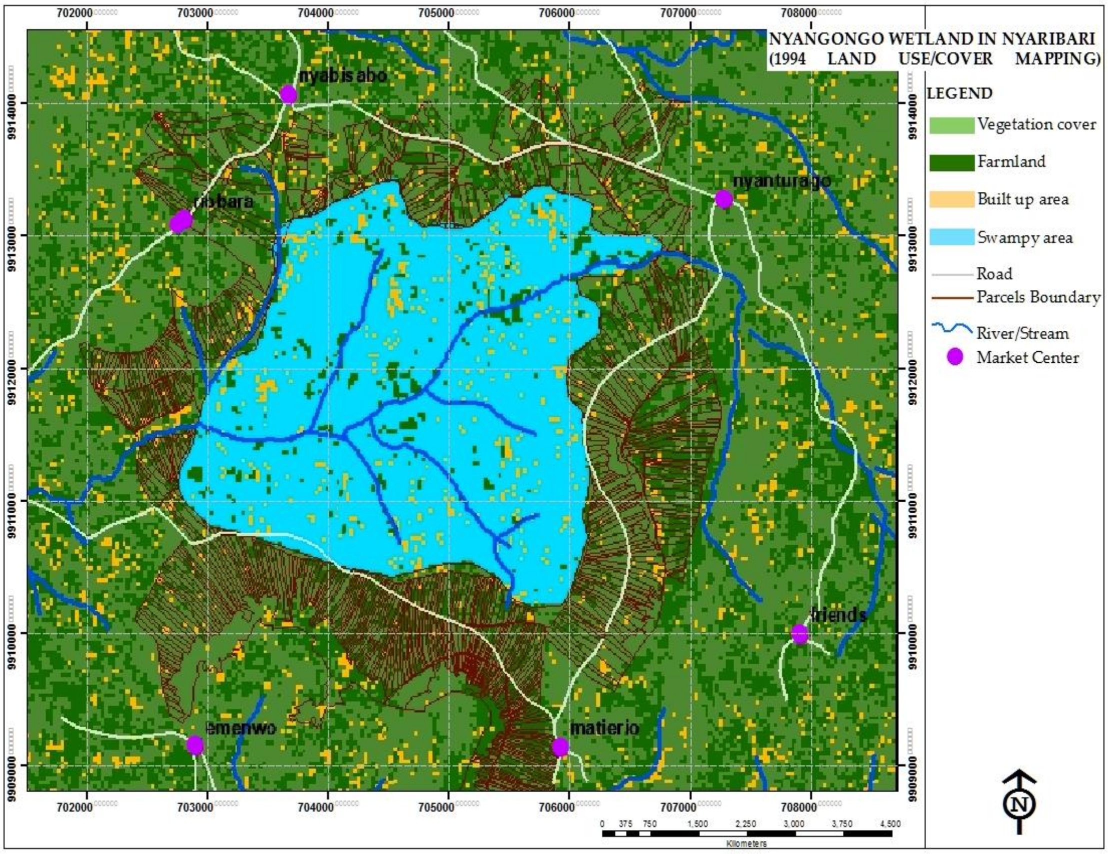

Figure 4.7 Land cover classification for Nyangongo wetland in 1994

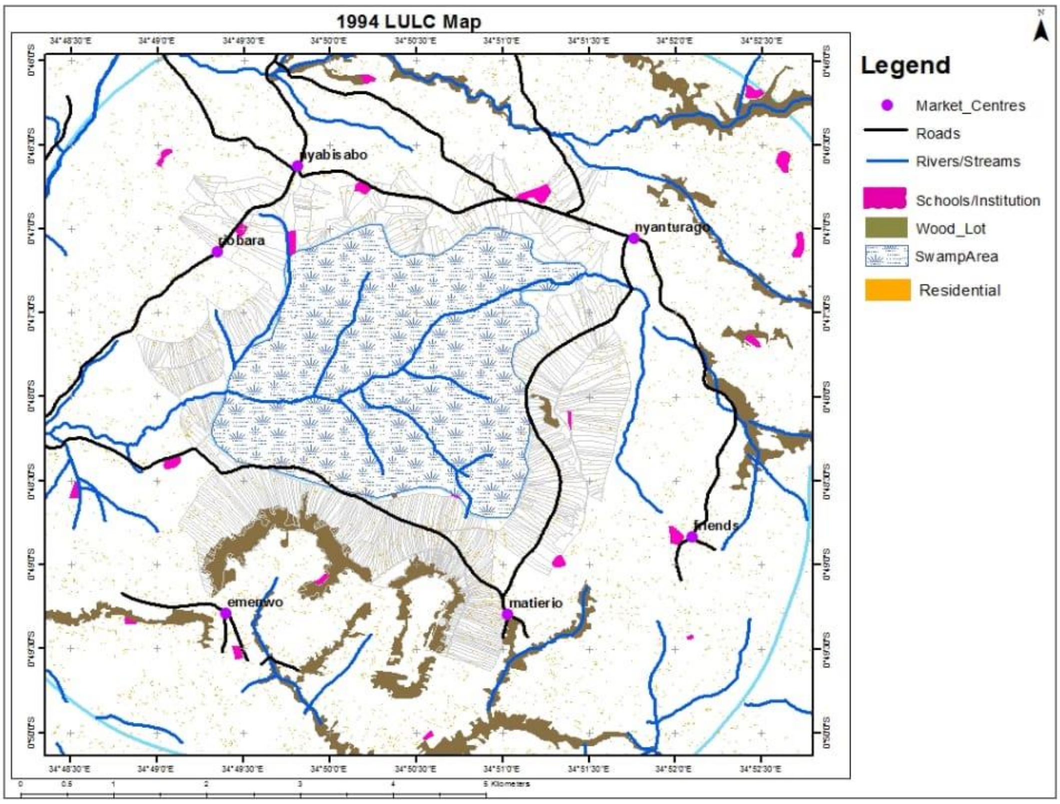

Figure 4.8: Land use Map for Study Area in 1994

4.3.3 Land use /Land cover in 2004

The research findings revealed that over a period of 20 years, the study area experienced major changes that were highly significant. Notably, the farmland and built-up areas had increased substantially. The farmland coverage increased by 73.15% from what it was in 1994 to 358.93 ha, representing 43.50% of the total area. Similarly, the built-up area expanded to 107.63 ha, accounting for 13.00% of the total area, which was a 28.44% increase from its coverage in 1994. This is attributed to increase of built-up areas on the wetland resulting to its shrinkage. This information is illustrated in Figure 4.9 below.

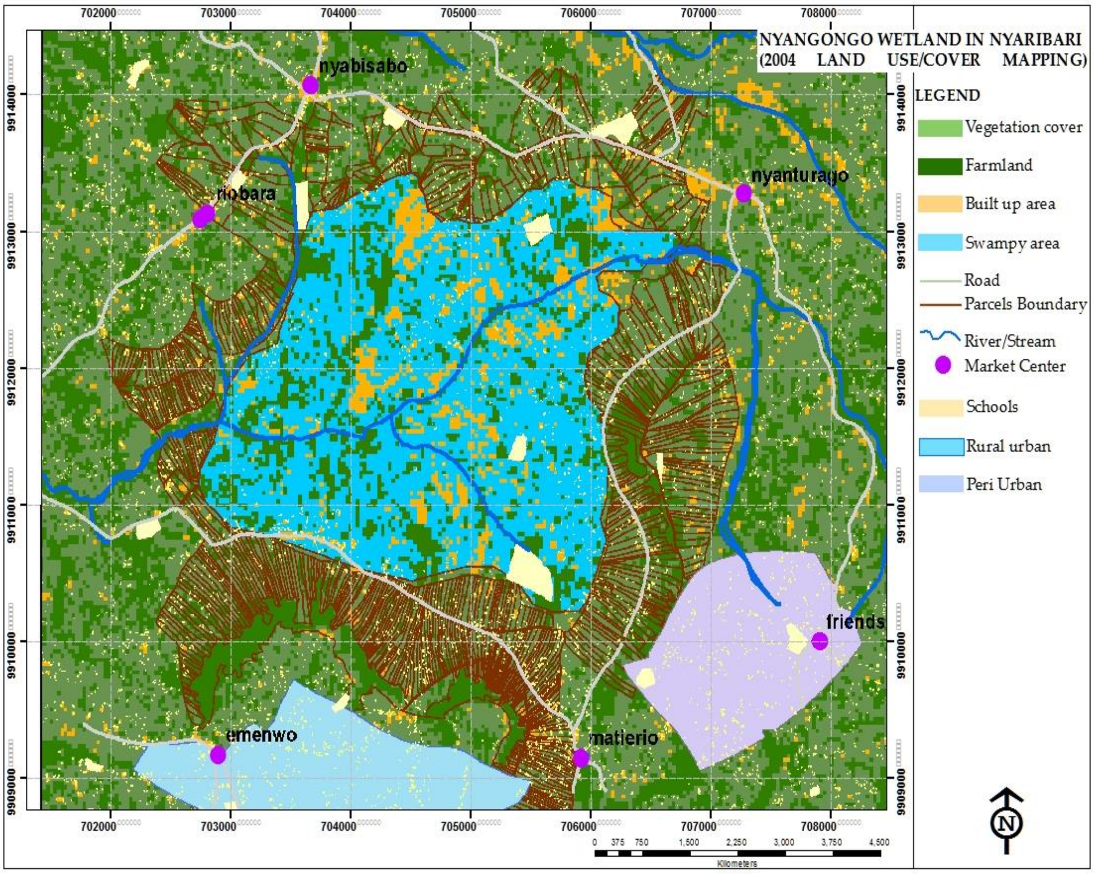

Figure 4.9 Land Cover Classification for Nyangongo Wetland 2004

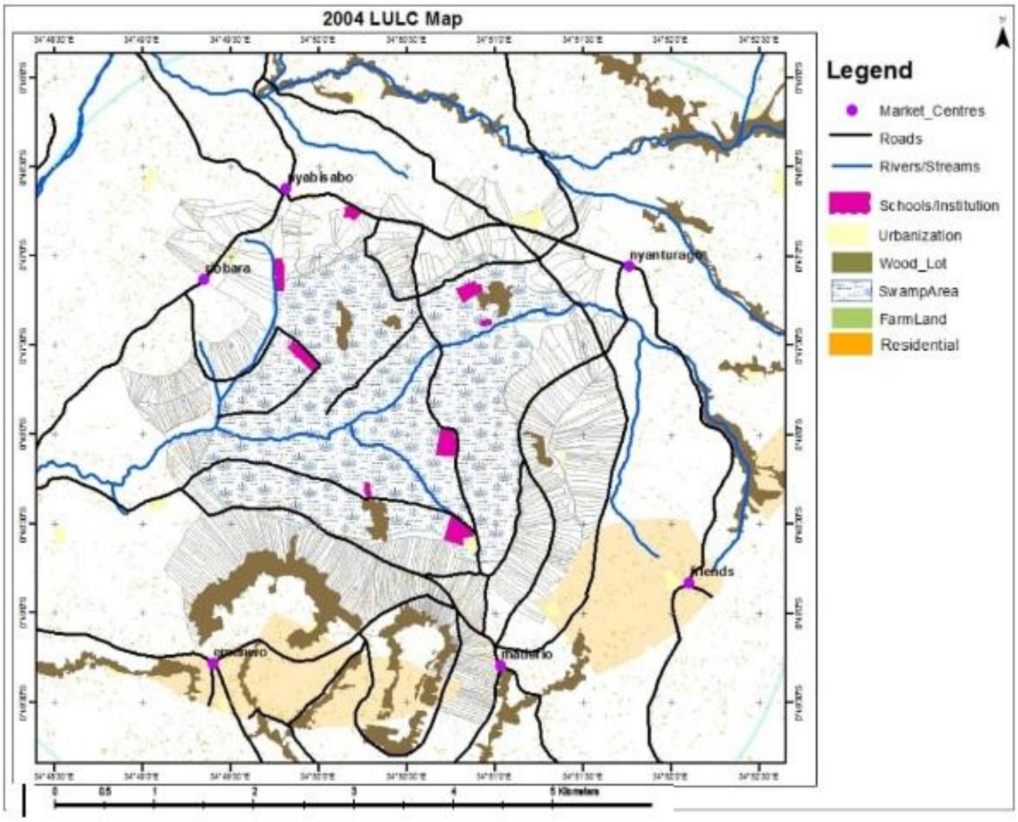

Figure 4.10: Land use mapping for Study Area in 2004

4.3.4 Land use /Land Cover in 2021

After a span of 37 years, the land use and land cover of Nyangongo wetland had significantly transformed. Farmland had the highest portion of 473.85 ha an increase of 114.87 ha (32%) of what it was seventeen years later. It was followed by built-up area at 185.14 ha an increase of 77.51 ha (72.02%) from the initial figure in 2004. The wetland area had shown slight increment of 5.01 ha from what it was seventeen years ago. Vegetation area showed significant decline to 148.86 ha from 346.30 ha in 2004, a decrease of 197.44 ha (57.01%). This is an indication that people were clearing vegetation to create more land for agricultural activities which were on high demand for consumption and income generating purposes. Figure 4.11 below supports the information provided.

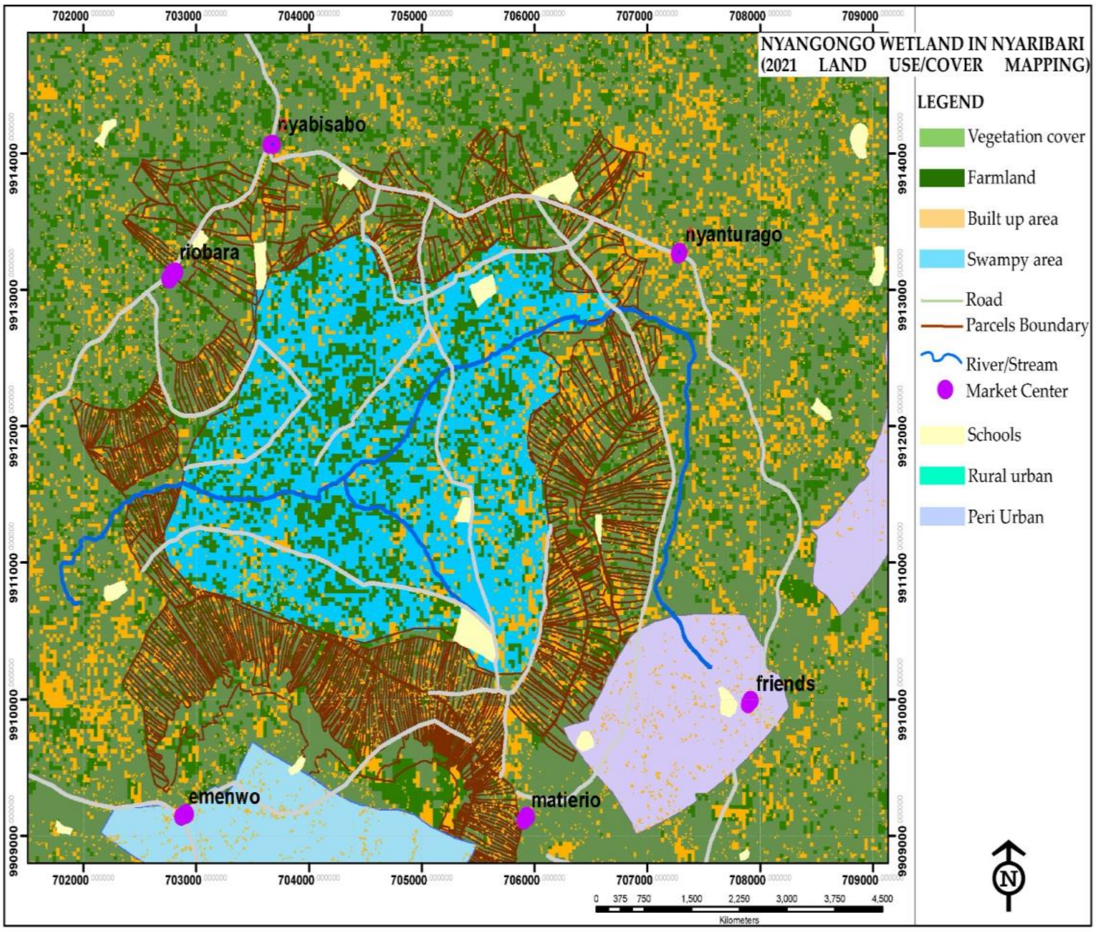

Figure 4.11 Land Cover Classification for Nyangongo Wetland 2021

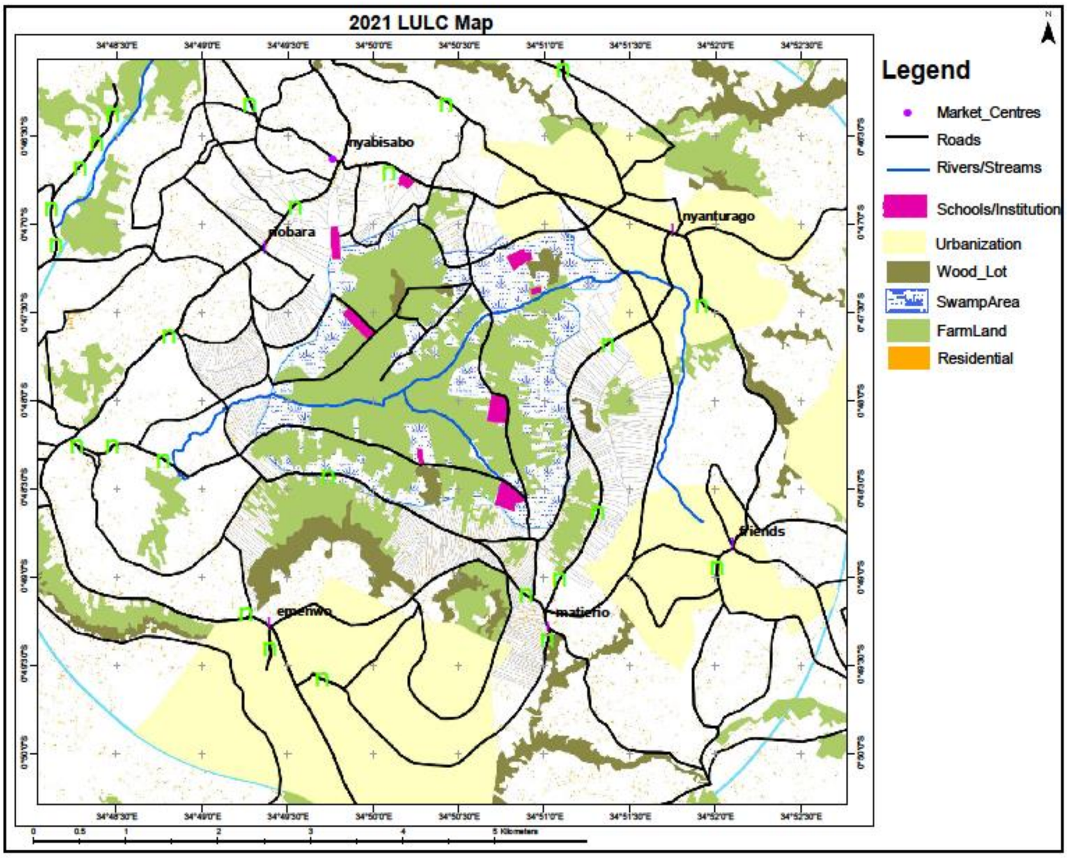

Figure 4.12: Land use map of Nyangongo Wetland and its environs in 2021

The figure 4.12 above indicates the prevailing human activities in the watershed such as cultivation agriculture, growth of eucalyptus and rivers draining the catchment area will impact on the wetland functionality. The information helped in supporting of the results obtained after image classification.

Table 4.4: Summary of Land use Land Cover Changes 1984 - 2021 in Nyangongo Wetland

Land use	**1984**		**1994**		**2004**		**2021**	
	Area(ha)	**Area (%)**	**Area(ha)**	**Area (%)**	**Area(ha)**	**Area (%)**	**Area(ha)**	**Area (%)**
Wetland	72.85	8.8	148.68	18.01	12.36	1.50	17.37	2.10
Vegetation	609.07	73.8	496.35	60.15	346.30	42.0	148.86	18.04
Farmland	135.65	16.4	96.39	11.68	358.93	43.5	473.85	57.42
Built-up area	7.65	0.9	83.8	10.15	107.63	13.0	185.14	22.44
Total	**825.22**	**100**	**825.22**	**100**	**825.22**	**100**	**825.22**	**100**

From Table 4.4 LULC analysis of the study area indicates quantified results obtained as per to the specified period of the study.

4.4 Land use/ Land cover change Detection

Satellite remote sensing data and Geographic Information Systems (GIS) have several applications in analyzing land cover, land use, and their transformations. Precise data about land cover is crucial for effective natural resource management, planning, and monitoring initiatives. Change detection involved ten-year interval analysis to detect changes between a pair of images that represent the initial and next phase of the study.

4.4.1 Land use/ Land cover change between 1984 and 1994

From the study there were significant changes in LULC that were noted during the study period. In 1994 there was drastic increase in wetland size after 10 years while on the other hand farmland depicted drastic change in size.

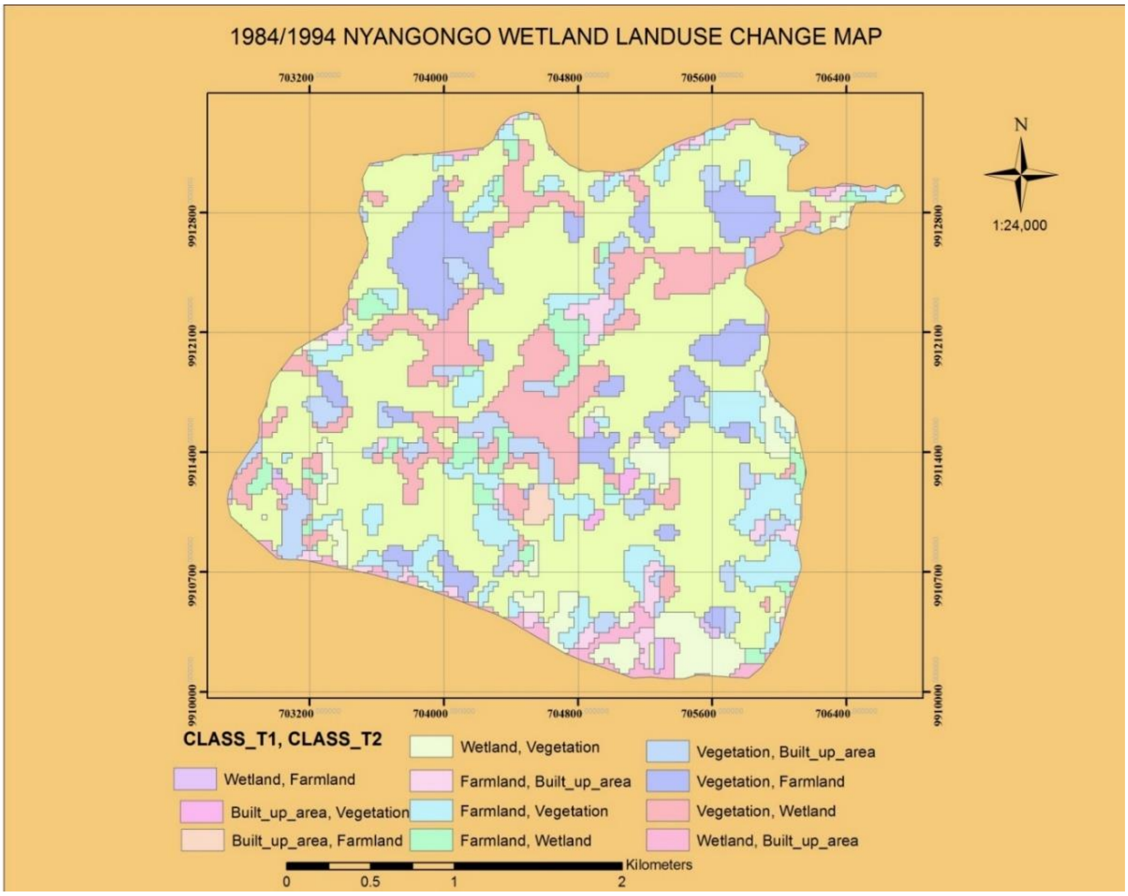

Figure 4.13: Land use Land Cover Change Map of Nyangongo Wetland (1984 to 1994)

Between 1984 and 1994 there were significant dynamics of LULC where for instance one land use had undergone conversion to other land uses as witnessed from the figure 4.13 above.

Table 4.5: Land use Land cover change matrix 1984 to 1994

		1994					
	class name	Wetland	Vegetation	Farmland	Built-up-area	Row total	Class change
1	Wetland	**13.4**	10.773	24.45	0.36	48.98	35.58
9	Vegetation	45.9	**37.116**	77.13	2.16	162.306	125.19
8	Farmland	3.87	77.49	**10.62**	4.41	96.39	85.77
4	Built-up-area	55.962	55.44	23.67	**0.81**	135.882	135.072
	Column total	119.13	180.819	135.87	7.74	443.561	381.612
	Class changes	105.73	143.703	125.25	6.93		

Of the total wetland area of 13.48 ha, 24.45 ha, 10.77 ha, and 0.36 ha were converted into farmland, vegetation, and built-up area, respectively. Similarly, regarding farmland as another valuable land use, out of the total area of 85.77 ha, 77.49 ha, 4.41 ha, and 3.87 ha were converted to vegetation, built-up area, and wetland, respectively, in a span of ten years (1984 to 1994).

4.4.2 Land use/ Land cover change between 1994 and 2004

Two decades after the initial study, there were notable changes in the land use and land cover (LULC) of the study area. Farmland and built-up area had shown a significant increase to cover 43.5% and 13.0% of the area respectively, while the wetland and vegetation areas had significantly decreased to only 1.50% and 42.0% respectively. LULC change matrix between 1994 and 2004 also depicted significant conversions of land uses. About 7.02ha, 1.26 ha and 1.08 ha of the wetland were converted into vegetation, farmland and built-up area respectively as can be seen in Table 4.6

Table 4.6: Land use Land cover change matrix 1994 to 2004

		2004					
	Class name	Wetland	Vegetation	Farmland	Built_up_area	Row total	Class change
	Wetland	**3.15**	7.02	1.26	1.08	12.51	9.36
1994	Vegetation	65.97	**212.4**	34.55	32.85	345.77	133.37
	Farmland	65.52	225.9	**34.2**	589.14	914.76	880.56
	Built_up_area	14.04	51.03	25.38	**16.47**	106.92	90.45
	Column total	148.68	496.35	95.39	639.54	1379.96	1113.74
	Class changes	145.53	283.95	62.19	623.07		

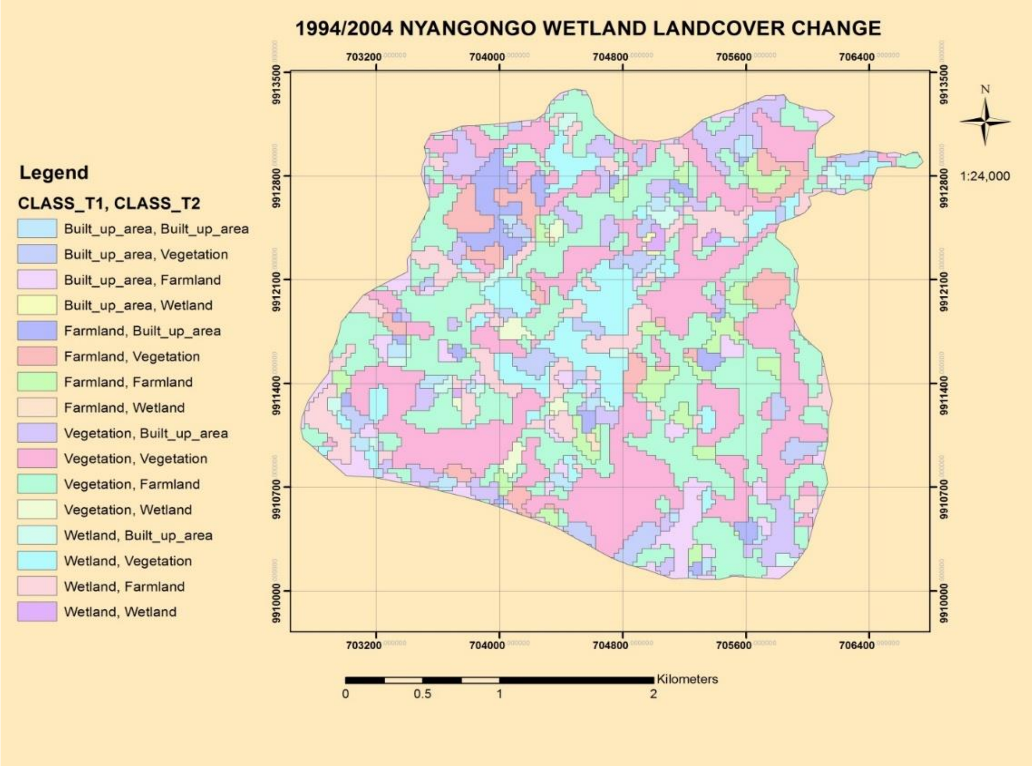

Figure 4.14 Land use land cover change between 1994 and 2004

4.4.3 Land use/ Land cover change between 2004 and 2021

During this particular period (2004 to 2021) wetland area had declined to 2.10%. Similarly, vegetation had declined to 18.04% which was a great decrease as compared to the previous period of 1984 to 1994 where the coverage was at 73.8%. The LULC change matrix during this last interval of study had shown a myriad of change dynamics where 4.68ha, 8.01ha and 2.97ha of the wetland were converted to vegetation, farmland and built-up area respectively. Similarly, 8.37ha, 200.8ha and 58.32ha of farmland were converted into wetland, vegetation and built-up area respectively. Total net increment of farmland and built-up area depicted continuous increment throughout the study period. In general vegetation dramatically decreased in the period between 2004 and 2017**.** Table 4.7 below shows summary of the results explained.

Table 4.7: Land use Land cover change matrix 2004 to 2021

		2021					
	Class name	Wetland	Vegetation	Farmland	Built-up_area	Row total	Class change
2004	Wetland	**1.71**	4.68	8.01	2.97	17.37	15.66
	Vegetation	0.9	**62.37**	61.2	24.39	148.86	86.49
	Farmland	8.37	200.79	**206.37**	58.32	473.85	267.48
	Built_up_area	1.53	78.93	639.18	**21.24**	740.88	719.64
	Column total	12.51	346.77	914.76	106.92	1380.9	1089.27
	Class changes	10.8	284.4	708.39	85.68		

4.4.4 Land use/ Land cover change between 1984 and 2021

At the end of the study period in 2021 the LULC had undergone tremendous changes which could easily be ascertained by the LULC classes. Overall, during this period, wetland and vegetation showed continuous reduction while on the other hand farmland and built-up area showed continuous increase in size. The extent of wetland in the study area reduced significantly from 72.85ha (8.8%) in the initial year of the study (1984) to 17.37ha (2.1%) in the final year of the study (2021). Similarly decline in vegetation cover was witnessed from 609.07ha (73.8%) in 1984 to 148.86ha (18.04%) in 2021. Furthermore, on the other hand farmland and built-up area had shown progressive increase of 135.65ha (16.4%) and 7.65ha (0.9%) in 1984 to 473, 85ha (57.42%) and 185.14ha (22.44%) in 2021 respectively. This illustrates the typical compromise that arises from the growth and strengthening of farming activities in wetlands, resulting in changes to the original vegetation and groundcover.

Table 4.8 Land use Land cover change matrix 1984 to 2021

		2021					
	Class name	Wetland	Vegetation	Farmland	Built-up-area	Row total	Class change
1984	Wetland	**0.36**	12.5	4.5	3.1	17.36	17.00
	Vegetation	8.1	**131.85**	7.47	1.44	148.86	17.01
	Farmland	54.36	310.5	**104.22**	4.77	473.85	369.63
	Built-up-area	559.71	156.96	22.68	**1.53**	740.88	739.35
	Column total	622.53	611.81	138.87	7.74	1380.5	1142.99
	Class changes	622.17	479.96	34.65	6.21		

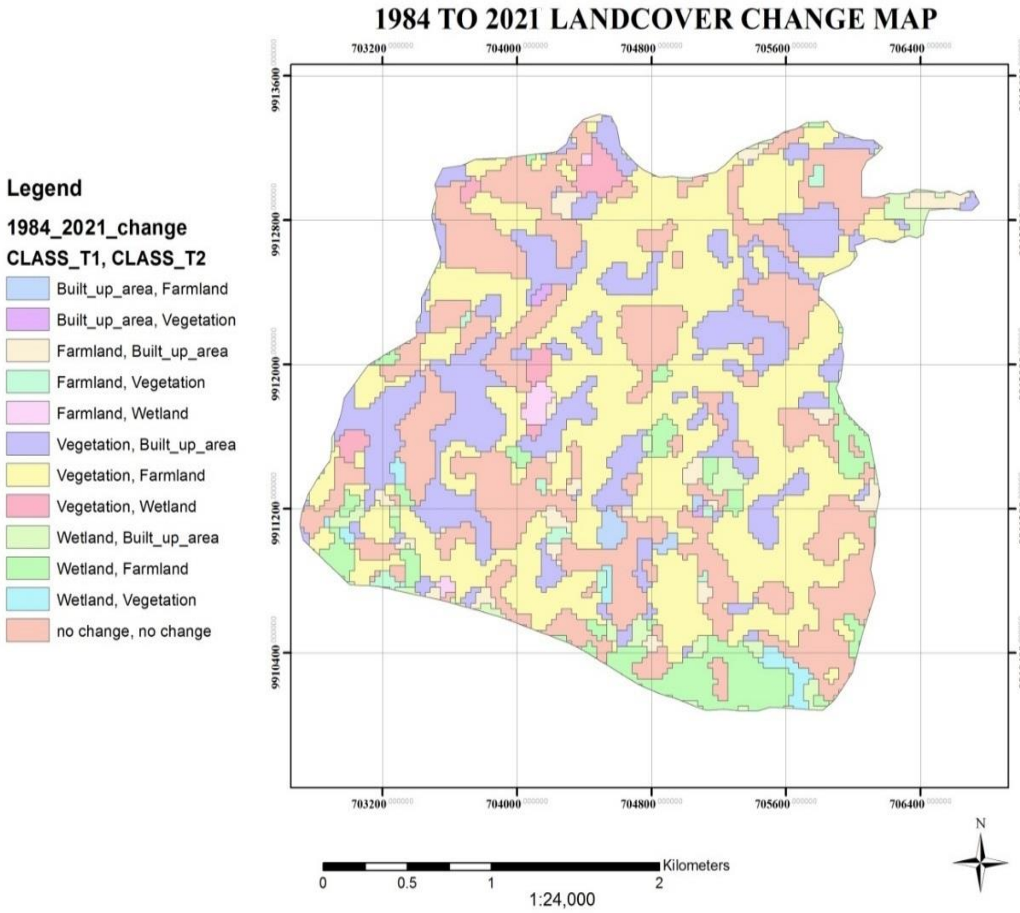

Figure 4.15: Land use land cover change between 1984 and 2021

4.5 Accuracy assessment for image classification

Upon completing the land cover and land use classification, an evaluation of accuracy was undertaken to guarantee its dependability. This was accomplished by contrasting the classified map with a reference map to determine the precision of the classification, as recommended by Caetano & Mata, (2005)

The standard method for reporting classification accuracy is through an error matrix, which is widely recommended and adopted Caetano & Mata, (2005)

Table 4.9 and **4.10** below represents a summary of accuracy assessment results for the years 1984 to 2021 that were used to extract data for the study period.

Table 4.9: Accuracy assessment for image classification

Class Type	1984 Accuracy (%)		1994 Accuracy (%)		2004 Accuracy (%)		2021 Accuracy (%)	
	producers	**users**	**producers**	**users**	**producers**	**users**	**producers**	**users**
Vegetation cover	86.5	86.5	68.3	87.5	85.5	79.1	95.0	80.9
Wetland area	77.5	91.2	74.4	69.0	72.5	80.6	85.0	79.1
Farmland area	84.2	71.1	71.1	77.1	82.5	73.3	95.0	86.4
Built-up area	90.6	93.5	77.4	60.0	85.5	91.7	57.5	88.5

Table 4.10 Overall accuracy and kappa coefficient statistics for land use land cover classification

Accuracy statistics of	1984	1994	2004	2021
Overall accuracy (%)	84.4	72.5	80.6	83.7
Kappa coefficient (%)	79.1	63.3	74.1	77.5

The precision of the supervised classification images from 1984 to 2021 were evaluated by conducting accuracy assessments. The utilization of Google Earth images of the research site and the Ground Control Points (GCPs) data acquired during field expeditions facilitated this procedure. The classifications' overall accuracy was notably high, varying from 72.5% to 84.4%. Additionally, the user accuracies were even greater, signifying that the majority of land cover changes were precisely identified and classified.

Kappa coefficient of Agreement (KCA) accuracy ranged from 63.3% to 79.1%. Based on the KCA values obtained, the classification accuracy was considered to be reliable (Jensen, 2005). Results ranging from 60% to 80% are considered as a substantial (good) measure of agreement of the two raters. This is a clear justification that classification of images was conducted as required.

4.6 To determine the human activities undertaken in Nyangongo Wetland

The study's second aim was to identify the various human activities carried out in the wetland area. This was meant to help take an inventory of the services on the wetland which will ascertain the actual current status.

In trying to find out the human activities conducted on Nyangongo wetland, a structured questionnaire was administered to household heads or alternative to provide anticipated information. The respondents were asked to tick some of the services they obtain from the wetland as indicated on the questionnaire. The results gathered are presented in Figure 4.16.

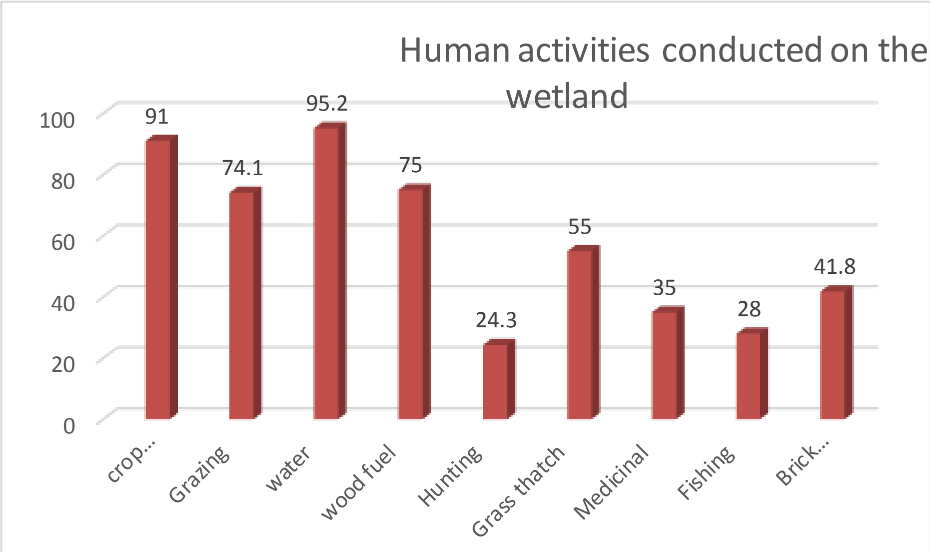

Figure 4.16 Human activities occurring on Nyangongo Wetland

Source: Author's field data (2021)

4.6.1 Livestock Grazing

The local community benefits from grazing their livestock on the wetland, as reported by 74.1% of the respondents. Livestock raised by the inhabitants consisted of various breeds such as exotic and indigenous cows, sheep, goats, and donkeys. During the study, it was noted that the grazing method used for cattle on the wetlands was either free-range or tethered. Plate 4.1 illustrates animals grazing on the wetland.

Plate 4.1: Livestock grazing on the wetland

Source: Author, 2021

Plate 4.1 above indicates that the wetland had been apportioned into grazing areas by the local community.

4.6.2 Crop farming

Crop farming is one of the activities some locals practice on the wetland to sustain their livelihood. This can be affirmed by 91% of the respondents who derive a living through agricultural expansion and intensification on the wetland. The main crops grown in the wetland are sugarcane, beans and maize. This can be depicted by Plate 4.2 and 4.3.

Plate 4.2 Agricultural Activities on the Wetland (sugarcane farming)

Source: Author, 2021

Plate 4.3 Agricultural Activities on the Wetland (maize farming)

Source: Author, 2021

These crops are grown in the wetland all year round and this has contributed to massive degradation of the wetland.

4.6.3 Fishing

The Nyangongo wetland was a significant source of fish for the locals, but its area had decreased over time, leading to a decline in fishing activities. The survey conducted revealed that fishing was limited to the wet season, when the wetland was suitable for breeding. Only 28% of the respondents reported obtaining fish from the wetland occasionally. To revive the fishing industry, the fisheries department introduced fish ponds, but the project faced challenges such as insufficient funding and inadequate management, leading to its failure.

4.6.4 Source of Water

According to the findings of the study, a large percentage (95.2%) of the respondents in Figure 4.16 reported that they use the wetland as a source of water for domestic purposes, watering their animals and crops. Many respondents valued the wetland for its role in providing water to their livestock and for irrigating their vegetables during dry seasons, particularly those grown near river banks. Moreover, the water resource in the region serves as a vital habitat for various types of biodiversity, including mudfish, which is caught and consumed by local people, especially during the rainy seasons when the wetland becomes waterlogged.

The Plate 4.4 below shows a water point in the wetland where the local community fetch water for domestic use.

Plate 4.4: Locals fetch Water from the Wetland Protected Spring for Domestic Use

Source: Author, 2021

4.6.5 Source of Wood Fuel

Concerning wood fuel as depicted in figure 4.16, over 75% of the respondents interviewed obtain fuel energy from the wetland. The inhabitants of the area engage in deforestation of the wetland vegetation for fuelwood like erythrina tomentosa, acacia mearnsii, croton macrostchyus, and other purposes such as processing sugarcane products. This has led to an unsustainable harvesting of vegetation, causing habitat and biodiversity loss in the region. This can be ascertained from analyzed satellite imagery of the area which indicates drastic decline in vegetation cover as compared to other land use types.

This vital resource was becoming scarce due to conversion of wetland forest to crop fields for purposes of enhancing food production.

Plate 4.5: An Elderly Lady Collecting Firewood from the Wetland

Source: Author, 2021

Table 4.11: Some Indigenous and Exotic Trees Grown in the Wetland Area

Botanical name	Common name	Indigenous/exotic	Use
Psidium guajava	Guava	Exotic	Firewood, human, animal feed & timber
Erythrina tomentosa	Omotembe	Indigenous	Medicinal, firewood &wood carving
Acrocarpus fraxinifolia	Omokina bwango	Indigenous	Medicinal& firewood
Sesbania sesban	Omosabisabi	Indigenous	Water filtration
Cassia didymobotrya	Omobeno	Indigenous	Medicinal
Triumfetta flavescens	Omomiso	Indigenous	Medicinal/firewood
Croton macrostachyus	omosocho	Indigenous	Timber/firewood

Source: Author, 2021

4.6.6 Medicinal Plant

The area is home to several indigenous trees that have various uses, including medicinal purposes. The local people gather roots, leaves, and barks from trees in the area to create natural remedies for a variety of illnesses, such as mumps, typhoid, coughs, and STIs.

Plate 4.5 below displays one of the medicinal plant found in Nyangongo wetland.

Plate 4.6 Acrocarpus *fraxinifolia* tree (Omokina bwango)

Source: Author, 2021

The results in Figure 4.16 shows that 35% of the participants reported that they utilize herbs from the wetland for therapeutic purposes. There are designated experts among the local community who have expertise in the diverse therapeutic properties of each plant for both humans and livestock. However, the transformation of the wetland and surrounding vegetation into farmland has caused a reduction in the availability of these plants, which are essential products obtained from the wetland.

4.6.7 Hunting

From the findings, 24.3% of the respondents said they rarely engaged in hunting activities. This is not common in the area as the wild animals have since declined in numbers due to loss of habitat as a result of alteration of the ecosystem. Only few wild porcupines and rabbits can be found in the area which locals could harvest for wild meat. These are the areas where hunting was taking place, mainly at the Gucha side. However, there was no indication of hunting being mentioned in some parts where intense vegetation clearing had taken place and agricultural activities were dominant, especially the Kisii central site of the wetland.

4.6.8 Thatching Grass and Fibre

The predominant and easily identifiable species of grass in the study area is (*Phragmites communis*) commonly known as common cattail grass. The Plate below shows a portion of curtail grass in the wetland.

Plate 4.7: Portion of Cattail Grass reflected on the Wetland

Source: Author, 2021

The findings displayed in Figure 4.16 indicate that 55% of the participants use thatch grass for different purposes. Thatch grass is used as a roofing material, but its use has been declining over time due to the preference for iron sheets. It is also used in handcrafts such as mat making and for fencing homes and bathrooms. While fiber resources are not abundant in the study area due to forest clearance for other activities, the remaining fibers are used for various purposes. In Abagusii culture, fibers are used to cover food during dowry payments. Fibers are also used in constructing mud houses to fasten rafters and thatching grass (reeds) to prevent water leaks during rainy seasons. Plate 4.8 below shows a grass tharched house using the product obtained from the wetland.

Plate 4.8: Grass thatched Residential House

Source: Author, 2021

4.6.9 Brick Making

The study showed that 41.8% of the respondents were engaged in brick making activities within the wetland for economic gain. The process involved baking a kiln of 5,000 bricks, which on average yielded around 4,000 intact bricks when the rest have been damaged. The selling price for a single brick at the time of the survey was Ksh. 10, meaning that one could earn up to Ksh. 40,000 after disposing of all the bricks.

Plate 4.9: Brick Making Activity on the Wetland

Source: Author, 2021

4.7 Regression analysis on human activities in relation to the Wetland ecosystem

In order to make a decision on whether or not a significant influence existed between human activities carried out in relation to wetland ecosystem, multiple regression analysis was performed to ascertain the same as represented by the findings in the Table 4.12.

Table 4.12: Results on regression analysis

Coefficients[a]					
Predictors: Human activities	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B(Beta)	Std. Error	Beta		
(Constant)	23.275	1.590		14.636	.000
CropFarming	-3.888	1.646	-.315	-2.362	.025
Grazing	4.750	1.901	.345	2.499	.019
Water	.108	1.646	.005	.065	.948
Woodfuel	-2.965	1.225	-.245	-2.420	.022
Hunting	.634	1.486	.037	.427	.673
Thatchgrass and Fibre	-6.535	1.323	-.556	-4.939	.000
Medicinal Herbs	2.690	1.458	.209	1.845	.076
Fishing	-1.030	2.082	-.078	-.495	.625
Brick Making	-4.389	1.684	-.367	-2.607	.014
Dependent Variable: Wetland					

Source: Author's field data (2021)

Regression of coefficient results in Table 4.12 shows that crop farming has a negative significant impact on wetland area (β_1= -3.888, p=0.025<0.05). It was further established that Wood fuel had also a negative significant impact on shrinkage of the wetland (β_2= -2.965, p= 0.022<0.05). Thatch grass had also a negative significant impact on the wetland (β_3= -6.535, p=0.000<0.05). Finally brick making was found to have a negative impact on the wetland area (β_4= -4.389, P=0.14<0.05).

This implies that a unit change in crop farming leads to a 3.888 ha decrease in wetland area. A unit increase of abstraction of wood fuel leads to a -2.965 ha decline of the wetland. A unit increase of harvesting of thatch grass leads to a -6.535 ha decline of the wetland area as a result of vegetation clearance and finally a unit increase of brick making leads to a -4.389 ha decrease of the wetland area due to loss of habitat and other essential wetland services.

4.8 To find out the causes influencing wetland encroachment

The study sought to find out what are some of the driving factors that influence the locals to engage in wetland encroachment and if they were aware of any conservation measures in place. The table 4.13 below shows the causes which have resulted to wetland reclamation and respondents' awareness on conservation measures.

Table 4.13: Drivers for wetland reclamation

		Awareness of wetland conservation measures					
		Yes	No	Total	Value	df	p-value
Reason for wetland reclamations	Shortage of crop and arable land	56(22.3%)	63(25.1%)	119(47.4%)	13.753[a]	3	0.003
	Decline of upland soil fertility	3(1.2%)	24(9.6%)	27(10.8%)			
	Lack of employment	23(9.2%)	42(16.7%)	65(25.9%)			
	High demand of agricultural products	12(4.8%)	28(11.2%)	40(15.9%)			
Total		94(37.5%)	157(62.5%)	251(100.0%)			

Source: Author's field data (2021)

Findings from the study indicate that 22.3% reclaim the wetland due to shortage of crop and arable land and they were aware of the conservation measures while 25.1% were reclaiming the wetland for the same reason but were not aware of the prevailing conservation measures. On decline of upland soil fertility, 1.2% they are aware of the conservation measures while 9.6% were not familiar with the same. Lack of employment was another driver where 9.2% of the respondents said was a reason for wetland reclamation and they were aware of conservation measures while 16.7% affirmed it was a factor for wetland reclamation but were not aware of any conservation measures to be observed. High demand for agricultural products was another reason why 37.5% of the respondents encroached on the wetland and they were aware of the conservation measures. On the other hand, 11.2% affirmed they said it was a reason for reclamation but were not aware of the conservation measures in place.

The variables were subjected to chi-square test and indicated that a significant relationship exist between drivers for wetland reclamation and awareness of wetland conservation measures ($\chi 2 = 13.75$, df = 3, p = 0.003).

4.9 Results from FGD and KII

The overall conclusions regarding the encroachment of Nyangongo wetland that were most commonly reported during focus group discussions (FGDs) and key informant interviews (KIIs) can be summarized into three main themes, which are presented below. Activities people carry out in the wetland, the drivers that encourage them to encroach the wetland and the current state of the wetland compared to 37 years ago. Most of the responses given during face-to-face interviews were displayed in form of *quotes and summarized statements.*

According to a respondent, Nyangongo wetland used to be an open area accessible to all community members until the 1970s. During this time, the population was low and the wetland was mostly left in its natural state with limited economic activities. The wetland was primarily used for cultural and social purposes such as fishing, grazing, gathering clay soils for house plastering and pottery, collecting thatch grass and palm materials for mat making, hunting, and recreation. At a certain time, the activities in the wetland did not have a significant effect on the wetland, and the *utilization of resources was still within the wetland's capacity. However, as the population grew due to natural growth, there were changes in land use patterns, ownership, and management, resulting in the extension of land subdivisions to the wetland area. This fragmentation of the wetland led to an increase in human activities carried out on the wetland.*

There was need to intensify agricultural activities for more food production which meant that the wetland was the only fallback for the land-thirsty individuals. At first since the wetland was water logged, people planted more eucalyptus trees to help withdraw water from the wetland as a way of reclamation. This has been going on as more land uses are being witnessed on the wetland which has led to its continuous loss.

Lack of coordination and support- The absence of effective cooperation among relevant parties was identified as a significant constraint preventing the achievement of sustainable wetland management. In addition, political intervention was reported to be a factor that accelerated wetland invasion.

Quote:

We do routine monitoring and inspection of the status of wetlands in Kisii County but we lack capacity in terms of personnel and finances to adequately effect the same. (NEMA Director-Kisii County). Also, the devolved government has always attempted to gazette the wetland as an industrial park for development of industries without considering the environmental impacts this is likely to pose to this ecosystem. This shows lack of political goodwill on issues involving wetland conservation and management. There is also, ignorance and lack of awareness on wetland management and conservation was mentioned (WRMA Staff)

Driving factors;

The respondents mentioned limited arable land, demand for more food production for commercialization, population growth and unemployment as the main issues for wetland encroachment.

The factors contributing to the encroachment on Nyangongo wetland are not limited to the issues presented earlier. Other factors such as poverty, population pressure, conflicts over resources, and the planting of eucalyptus trees on the wetland also have a significant impact on the sustainable use of the wetland.

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This chapter provides an analysis of the research results presented in the previous chapter, organized according to the stated research objectives and connected to the relevant literature that aligns with this study. It begins with the first objective which was on spatial-temporal analysis of land use land covers on the wetland. The second objective entails determining the human activities conducted on the wetland and the third objective was to find out the causes of wetland encroachment in relation to awareness on conservation measures.

5.2 Spatial-temporal analysis

The first objective of the study was to analyze the extent and nature of land use and land cover changes that have taken place in the Nyangongo wetland. The study found that the wetland and its surrounding area have undergone changes in land use and land cover. The primary land uses found in the wetland include natural vegetation, agricultural land, developed areas, and the wetland itself. Findings presented on Table 4.4 showed that agricultural activities have accelerated the loss of wetland areal extent.

Expanding wetland cultivation causes vegetation loss, which in turn results in reduced ecosystem services like flood attenuation, erosion control, recharge of underground aquifer and wild food. Additionally, wetland agriculture and drainage reduce the soil's water storage and regulation functions, and the water table level is lowered. This phenomenon is common after wetland cultivation and has been observed in various studies. To provide an example, in the Rugezi Marsh located in Rwanda, the draining of channels had a detrimental effect on the water table, causing peak flows to increase and resulting in the drying up of the swamp Agibola et al. (2012) The drainage also impacted the ability of soil to store water, with reduced infiltration capacity due to oxidization conditions. Additionally, tilling of soils for farming purposes caused compacted soils and decreased soil infiltration capacity Peng et al., (2009)

Agricultural activities that are carried out intensively have a detrimental effect on water quality as a result of the increased quantity of contaminants like fertilizers, disinfectants, and pesticides. The presence of these chemicals has an unfavorable influence on human health and the quality of wetland-derived drinking water (Richards & Richards, 2022)

5.3 Human activities occurring in Nyangongo wetland

The second objective was to establish the human activities carried out on Nyangongo wetland. The wetlands provide various resources and benefits to the community, such as water for brick making, drinking, and washing, as well as food in the form of wild fruits, fish, meat, and vegetables. Additionally, people harvest thatch grass and palm trees for domestic use such as basket and mat making. Wetlands also have educational value, as researchers and students visit them for academic purposes, as seen in South Africa (Day & Malan, 2010). These practices have declined over time due to land use and cover changes leading to a reduction in the size of wetlands. However, some of these services have been replaced by crop cultivation, which has been increasing over time. However, farming along riparian areas has led to soil erosion and water pollution, which can have long-term effects on aquatic life and human health. Mitsch et al. (2012) found that wetland conversion to cropland accounted for the largest share (83%), which amounted to 1.5 million hectares of wetland loss in the U.S. This is similar to the situation in Nyangongo wetland, where agricultural activities account for a large portion of 473.85 ha of the total area of the wetland (825 ha) as compared to other land uses.

Uncontrolled grazing leads to a decline in the vegetation of wetlands, causing the formation of hard pans and nutrient addition to the water, which increases pollution and eutrophication, leading to a compromise in water quality Peng et al., (2009). The impairment of wetland filtration function results in high levels of environmental pollution. This can cause an increase in carbon dioxide levels and depletion of the ozone layer, which can lead to diseases such as skin cancer in human beings. Grazing pressures may lead to soil compaction, which can reduce water infiltration, increase runoff and erosion, and reduce groundwater recharge during the flood season. However, research by Agibola et al. (2012) indicates that the impact of livestock grazing on species composition ultimately affects the structure and function of wetland vegetation.

Wetlands play a crucial role in replenishing groundwater resources, which subsequently helps to recharge rivers and streams for the supply of water for various purposes. However, the excessive planting of eucalyptus trees along riverbanks has resulted in the drying up of most rivers and streams, as stated by the NEMA Director in Kisii County. This is due to the high-water consumption rate of eucalyptus trees, which has significant effects on the replenishment of groundwater resources in the study area. Eucalyptus trees, commonly grown in agroforestry, consume significant volumes of water, as supported by research conducted in Pakistan by Muhamed and Nawaz (2007). These findings align with what was reported by one of the respondents in the study area, where locals have penetrated the wetland and started planting eucalyptus trees to drain it for settlement and agricultural activities.

In the next 15 to 25 years from the year 2015, the proportion of areas in Africa that are facing relative water scarcity is expected to decrease from approximately 53% to 35%, affecting around 600 million individuals. Some predictions indicate that by 2025, up to 16% of Africa's population (equivalent to 230 million people) will reside in countries with limited access to water, while 32% (approximately 460 million people) will live in nations with water scarcity issues. These figures were reported by IAASTD in 2019. This calls for a concerted effort from all stakeholders to ensure that conservation and management of wetland is key for prosperity.

The study findings further showed that some members of the community depend on wood fuel which they harvest from the wetland. The replacement of indigenous vegetation with eucalyptus trees has negative impacts on water resources and suppresses the growth of native plants. Eucalyptus species are widely used in plantation forestry due to their fast growth, adaptability, and multiple uses, leading to their dominance over indigenous tree species in many countries Bayle, (2019). However, in areas such as California, the large-scale growth of eucalyptus has led to the replacement of oak woods, which has raised environmental concerns Mitsch et al., (2012). When ecosystems are manipulated to provide goods and services, it can negatively impact species composition, diversity, and ecosystem resilience. As a result, these ecosystems may become unstable and require significant inputs to maintain their productivity and stability.

The local community also obtain medicinal herbs from the wetland as indicated in Table 4.16. Some of these plants have declined over time due to conversion of the wetland to agricultural areas for crop production and pasture lands. The results of this investigation are consistent with Huho et al., (2015)research, which revealed that wetland plants offer a diverse range of medicinal resources to communities living along rivers. In addition, the roots of wetland vegetation anchor the soil and deposit sediment on the wetland floor, preventing soil erosion downstream and decreasing the water's erosive force.

Thatch grass and fiber were also some of the products the local community obtained from the wetland. The results of this study support the observation made by Poff, (2002) that various elements of wetland ecosystems offer direct human consumption resources, such as fibers and reeds that can be used for thatching houses and handcraft industries. The study findings are also consistent with the WWF and World Bank (2010) report which states that wetlands offer a range of goods and services that have considerable economic value not only for the nearby communities but also for those residing beyond the wetland area.

Brick making has been thriving as the demand for these products is high because of ready market and proximity to the upcoming urban centers such as Nyanturago market, Keumbu, Kiamokama, Nyamache, Nyabisabo and the larger Kisii town which require supply of bricks for construction. However, there are some adverse ramifications associated with the same as it results to environmental deterioration. The wetland's biodiversity has been changed, and the overall terrain has been affected by the extraction of clay for brickmaking. Clearing of wetland vegetation for burning bricks exposes the land to floods as erosive power of surface runoff is increased. This leads to decline of water purification and loss of biodiversity which are essential services provided by the wetland. When thermal temperatures in the wetland increases, it results to reduction of oxygen levels in water which consequently suffocates fisheries such as mudfish that has led to their decline over time. The alteration in temperature resulting from climate change could lead to unfavorable conditions for the current species that inhabit the wetland ecosystem, making it challenging for them to adapt and survive, Poff, (2002). The loss of connections between wetlands and waterways could occur due to increased temperatures and reduced precipitation, preventing many fish species from migrating to other systems. As noted by Poff, (2002). the rise in temperature could also have an impact on cold or cool water fish species, as they rely on wetlands for nursery areas and may no longer be able to utilize these regions due to the rise in temperature.

5.4 To find out the causes influencing human encroachment on the wetland

From the findings, wetland reclamation is enhanced due to high demand of agricultural products such as sugarcane, finger millet and bananas which boost income levels of the local community. The higher demand for such crops is enhanced by the ready market available in nearby urban areas and the rest ferried to other urban areas like Nairobi, Nakuru, Kisumu and Eldoret. Thriving of the aforementioned agricultural activities is supported by the ambient climatic conditions prevalent in this area coupled by the wetland’s proximity to the nearby tarmac road that makes it easier for transportation. These factors have immensely contributed for continuous unwise utilization of this wetland. This was also ascertained with the wetland excursions that were conducted during the study period to assess the dominant land use activities on the wetland. This was also attested via key informant participants such as WRUA, NEMA Director and sub-county Forest officer who said crop production for subsistence and commercialization was a major factor resulting to wetland degradation.

This has increased the quest of local farmers to apply more agricultural inputs such as fertilizers to enhance quick maturity to increase their economic security to sustain their livelihoods. These agrochemicals are lethal as compared to organic manure as they are washed into the water resources thus compromising the water quality.

Preserving wetlands in low-income countries can be challenging due to competing priorities such as poverty and food security, often overshadowing environmental protection concerns. To effectively manage and conserve wetlands, it is crucial to involve and educate local communities on their importance and the impacts of human activities. Indigenous communities can be particularly helpful in conservation efforts by bringing traditional knowledge, skills, and practices. Their participation can aid in striking a balance between conservation goals and daily needs.

There are signs of decreasing soil productivity due to continuous farming, leading to a reduction in organic matter content. While transforming the wetland into farmland might provide immediate benefits, it will result in long-term challenges such as increased expenses and reduced crop yields due to irreversible soil fertility depletion, causing economic, social, and environmental issues. This was also supported by findings from FGD as one of the major factors enhancing wetland encroachment and reclamation.

The laws and regulations in place to protect wetlands from being overused are often ignored by rural populations due to socio-economic challenges, leading to the unsustainable use of these natural resources. The expansion of agriculture in different parts of the world has been associated with the loss of natural vegetation cover, as documented in various studies.

According to the study, the major cause of wetland ecosystem degradation and loss is agricultural expansion, which involves the clearance of vegetation and drainage of wetlands. Other studies in developing countries, such as those conducted by Rosolen et al., (2015) also reported similar findings. Agriculture is essential to the livelihoods of rural communities in semi-arid regions of Zimbabwe, as suggested by Okeyo-Owuor et al., (2012) which could explain the increase in wetland farming.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This section offers a condensed overview of the study's outcomes, deductions, and advice based on the results. The subsequent subsections offer more detailed information.

6.2 Summary of findings

According to the study, over the last 37 years, Nyangongo wetland has undergone significant transformations, transitioning from a mostly untouched environment to a landscape primarily managed by humans, with agricultural fields and settlements dominating the area. It is crucial to strike a balance between utilizing natural resources to promote food security and development while preserving and sustaining the wetland ecosystem.

The main aim of the investigation was to evaluate how the usage of land on the wetland has altered over time and space. Based on the research findings, Nyangongo wetland continues to face adverse threats which may eventually lead to its degradation and loss. The extent of wetland area increased by 75.83 ha between 1984 and 1994 but drastically decreased by -136.32 ha between 1994 and 2004. It also slightly increased by 5.01 ha between 2004 and 2021. In general, the extent of wetland decreased significantly despite the intermittent fluctuations witnessed during the study period. Based on the findings presented in Table 4.4, it was discovered that over the last 37 years, the wetland area has reduced by 55.48 hectares, which accounts for 76.2% of the total wetland area in 1984.

In terms of significant wetland loss, agricultural activities have been on the rise over time in the wetland ecosystem. The wetland's farmland has expanded through the clearance of its natural vegetation, in order to accommodate the growth of agricultural fields and settlements. Therefore, this research found out that Nyangongo wetland had been shrinking over time.

The second research objective sought to establish the human activities carried out on Nyangongo wetland. They were found to be water abstraction, crop farming, fishing, thatch grass collection, land for pasture, harvesting medicinal herbs, brick making and wildlife hunting.

The respondents indicated the products they obtain from the wetland in terms of their prevalence in sustaining their livelihoods such as water, thatch grass, medicinal herbs, fisheries, and pasture. The decline of water resources for instance affects members of the community who travel for a long distance seeking for the same.

The third objective of the research was to determine the motivators behind human encroachment upon the wetland.

The principal drivers of continued shrinkage of Nyangongo wetland coverage include increased demand on agricultural products, lack of employment, limited arable land and decline of upland soil fertility. The swift expansion of the human population has led to a shortage of available land and the overuse of resources in the wetland. A dearth of livelihood options and employment opportunities has prompted individuals to encroach upon and exploit the wetland's resources.

From the findings it was clear that 157(62.5%) of the respondents alluded they engage in wetland conversion as a result of the aforementioned factors but were not aware of the wetland conservation guidelines. This was in comparison to 94(37.5%) who consented to have been versed with the prevailing conservation measures. This is a clear indication that reclamation of wetland is harnessed due to lack of information which ought to be escalated to community levels by relevant authorities.

6.3 Conclusions

The degradation of Nyangongo wetland is largely due to changes in land use and land cover caused by human activities. The study aimed to measure the extent of these changes in the wetland over the past 37 years and found clear evidence of modifications in the land cover during this period.

After conducting an assessment and examination of human activities taking place in Nyangongo wetland and their consequential effects on the area, it is critical to prioritize the restoration of the wetland to recover its essential ecosystem services. This is vital for the welfare of the present and forthcoming generations.

According to the study's findings, agriculture remains the primary form of land use responsible for the loss of wetlands, which has led to elevated levels of surface runoff, erosion, flooding, pollution, and the decline of biodiversity and habitats.

In general, from the findings it depicts that land use change has enormously impacted on this resource and to the community’s livelihoods. Moreover, by understanding the human induced factors resulting to changes in LULC change, relevant stakeholders can utilize the information to come up with intervention strategies and sustainable land use systems to conserve natural resources. It is necessary to make significant changes in mindset and promote awareness, as well as establish appropriate legislation, to preserve the natural integrity of these vulnerable ecosystems for future generations. Developing and executing viable management plans for wetlands is crucial to ensuring their sustainability, and is a mandatory aspect of the Ramsar Convention (1971).

6.4 Recommendations

The aim of wetland management is to prevent activities that may cause permanent damage to the wetland and promote responsible usage. Establishing community-based organizations can assist with the management of natural resources. Below are some of the suggested strategies:

1)Vegetation Restoration

The local community to be supported and encouraged to grow palm trees, bamboo, acacia which are environment friendly. These will help them generate some income to sustain their livelihoods. Palm and bamboo can be used to extract craft materials to help the community make mats, chairs which they will sell to the local markets and even export to international markets to earn a living. This will help them meet their daily needs such as paying school fees, meet medical bills and purchase food. Through these initiatives they will be willing to adopt conservation measures without any confrontation as they will own the initiative.

2) Wetland grazing

To prevent excessive grazing, it is crucial to establish the wetland's carrying capacity and limit the number of animals allowed to graze within its confines. It is best practice that community members to be harvesting grass from the wetland other than bringing their livestock for grazing as a remedy to control overgrazing. The grass should be sold at a fee in bales and Income generated to be used for maintaining the wetland.

3) Public awareness

It is crucial to educate community members on the detrimental effects of their activities that lead to wetland degradation, such as excessive use of agro-chemicals and planting water-demanding species like eucalyptus trees. The community should take responsibility for the wetland and understand that the government is responsible for managing it. Encouraging sustainable land use practices, such as organic farming, that do not harm the wetland should be a priority. Involving the local community's wisdom and expertise in wetland management is crucial to ensure that they understand the significance, advantages and functions of wetlands.

4) Impact assessment and continuous monitoring of wetlands

Before any form of development, such as draining for agriculture or institutional development, it is essential to conduct a thorough environmental impact assessment (EIA). This will ensure that the proposed modifications do not have harmful consequences on the wetland. A concerted effort for continuous wetland monitoring to be implemented by NEMA and the county government to avoid any inappropriate activities on the wetland.

5) Cultivation on wetlands

The riparian community around Nyangongo wetland can be helped by the county government and other stakeholders to adopt new technology on agricultural production that thrives better on waterlogged areas without impacting on the natural resource. This technology entails soil-less cultivation (hydroponics) which has been tried and succeeded in other countries such as Bangladesh.

Soil-less cultivation methods, such as hydroponics, can help reduce the strain on arable land by utilizing wetlands as a base for rural economic activities without affecting the natural characteristics of the ecosystem. The use of hydroponic systems in agriculture consumes less water and nutrients compared to traditional soil-based agriculture, and the nutrients used are recycled. This leads to less water pollution since there is a decrease in the amount of agrochemical runoff. Additionally, the compost produced through hydroponic systems can be used to improve the organic content of soil-based agriculture, which reduces the expenses incurred in purchasing inorganic fertilizers and provides an additional income source if sold.

The implementation of hydroponics can have a positive effect on open water fisheries by addressing issues related to weed congestion and utilizing nutrients present in the water.

The aquaculture sites proposed by the researcher to be installed on the wetland will utilize this technology and will contribute to the revitalization of the local economy.

Some of the crops to be grown by this technology include; cucumber, eggplant, pumpkin, spinach, tomato, potato, cabbage, carrot, onion, garlic turmeric etc. This can be sold for income generation. Some of these economic activities will help community members to diversify their livelihoods so that they are less dependent on unsustainable agriculture and brick making and at the same time are able to comply with guidelines on wetland use without suffering economic hardship. County government should constitute a wetland management committee that will be overseeing and managing the wetland.

6) Planning Intervention

It is important to ensure that the use of wetlands is consistent with their natural potential in order to achieve long-term sustainability of natural resources.

This can be determined through an extensive inventory of ecosystem services as a guide for implementing viable strategies. The actions taken to address wetland degradation should be culturally and socially appropriate, respecting local knowledge and capabilities. They should be community-led to ensure social acceptance, economically reasonable, and self-sustainable, contributing to the community's economic development and overall living conditions. To ensure long-term viability, the planned measures should account for the local population's ability to adopt technology, organizational and economic changes, and their willingness to do so.

Hence, the conservation of wetlands is considered a profitable endeavor that sustains the well-being of the local communities. However, the impact of conservation on the livelihoods of the poor often goes unnoticed by the researchers and policymakers, as noted by Fisher, R.J et al (2005). Fisher argued that conservationists have neglected the costs of conservation to the livelihoods of the impoverished and the uneven distribution of these costs. Therefore, the effectiveness of wetlands conservation initiatives should focus on launching programs that enable people to meet their livelihood needs. The inhabitants living in proximity to the wetland should be encouraged to explore alternative sources of income, such as beekeeping, aquaculture farming, establishing tree nurseries, and developing cottage industries to supplement their livelihoods as reflected in the diagram on the next page.

WETLAND SPATIAL PLAN (WSP) FOR IMPLEMENTATION

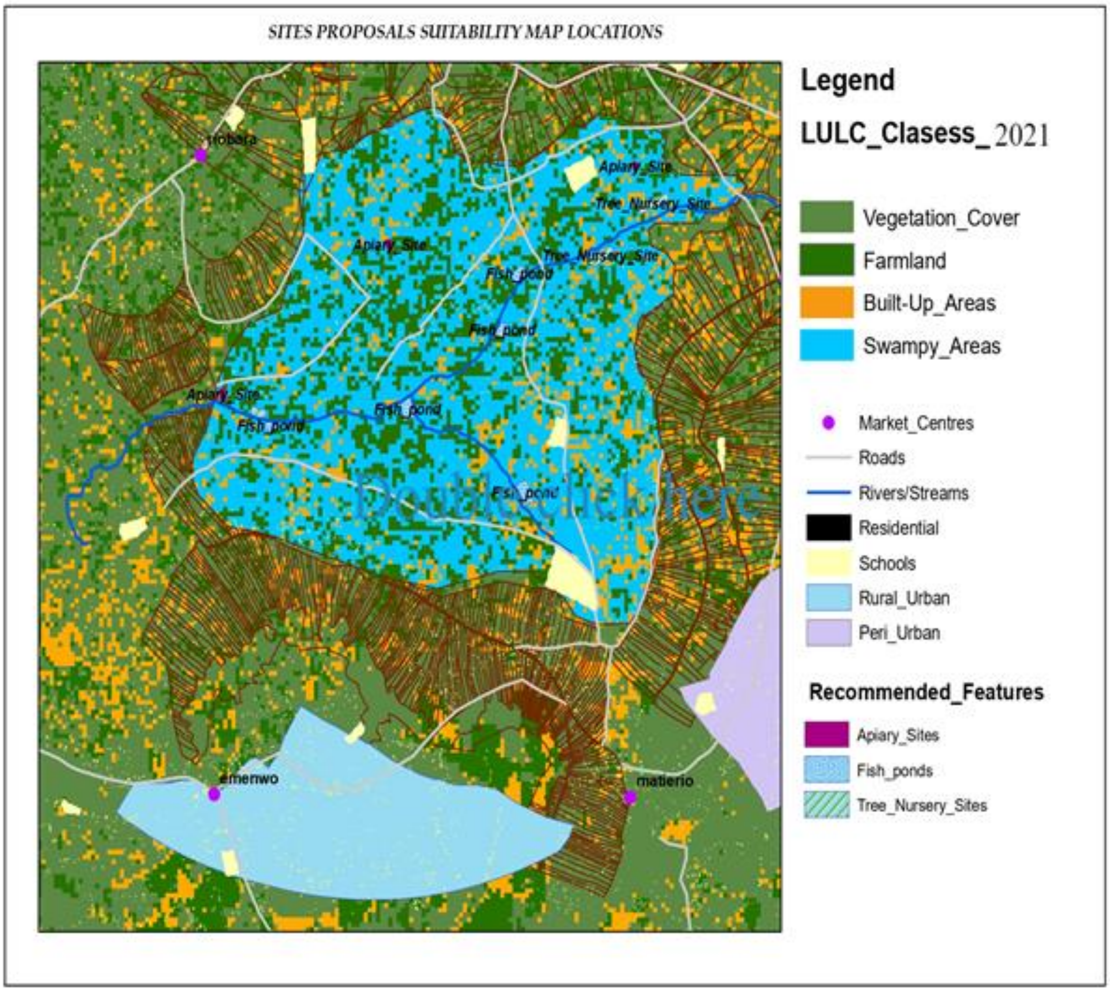

Plate 6.1: Suitability sites

6.5 Future areas of Research

- A further investigation should be carried out to determine the total economic value of the wetland as it was not included in this study.
- Study on climate change issues that may lead to ecological effects of the wetland is also recommended. This was suggested as among the emerging issues on wetland degradation by the sub-county forest officer. This will help gain more understanding on how natural factors contribute to changes on wetland functioning in relation to anthropogenic activities that will help develop robust management strategy.
- During the study, it was evident during heavy rainy seasons, pit latrines get filled up and there was overflow of human effluent hence contaminating water resources which poses a health hazard. The study suggests that additional research should be undertaken to analyze and monitor the quality of water in the wetland, with the aim of gathering both qualitative and quantitative data on pollution, eutrophication, and nutrient levels.

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APPENDICES

Appendix I: Household Questionnaire

I am a student, currently pursuing a Master's degree at the School of Environmental Studies, University of Eldoret. As part of my degree requirements, I am conducting research on the effects of land-use practices on the wetland ecosystem, focusing on Nyangongo wetland in Kisii County, Kenya. I would appreciate your help in completing this questionnaire, which will aid in my academic research. The information you provide will be kept confidential. Your cooperation would be greatly valued.

Thanks in advance.

Enumerator: …………………………………….

Date of interview: ……………………………………..

1. PERSONAL INFORMATION (BIO-DATA)

1. Name of respondent (Optional) ……………………………………………….

2. Gender

1) Male ( )

2) Female ( )

3. Marital status

1) Married ( )
2) Unmarried ( )
3) Widower ( )

4. Age brackets in years

1) 18-25 ( )
2) 26- 35 ( )

3) 36 -45 ( )

4) d) 46-55 ( )

5) Above 60 ( )

5. Education level

1) Primary school ( )

2) Secondary school ( )

3) Tertiary education ( )

6. Family size

1) 1-4 people ( )

2) 4-6 people ( )

3) 6-9 people ( )

4) More than 10 ( )

7. Village

1) Kabosi ( )

2) Kegochi ( )

3) Nyamagwa ( )

4) Nyangongo ( )

8. Sub-location …………………………………………………………

9. Gross income per month (please tick as appropriate)

1) Below ksh 2000 ( )

2) Kshs 2000- 5,000 ( )

3) Kshs 5,000 – 10,000 ( )

4) Kshs 10,000 – 20,000 ( )

5) Above kshs 20,000 ( )

10. For how many years have you lived in this area?

1) Less than 10 years
2) 11-20 years
3) 31-40 years
4) 41-50 years
5) Over 51 years

2. WETLAND OWNERSHIP, UTILIZATION AND MANAGEMENT

1. How did you acquire this piece of land on the wetland?

1) Through self-allocation.
2) Through purchasing (Bought)
3) Via renting
4) Others specify…………………………….………………………

2. What benefits do you gain from Nyangongo wetland? Please tick as applicable.

Activity	**Mark (x) or (Tick)**
Grazing	
Thatching grass and fiber	
Wood fuel	
Water for domestic use	
Medicinal herbs	
Hunting	
Fishing	
Crop farming	
Others (specify)	

3. In your opinion, what do you think encourages people to engage in wetland conversion / reclamation? (Tick where applicable)

1) Shortage of crop and arable land ( )
2) Decline of upland soil fertility ( )
3) Lack of employment ( )
4) High demand of agricultural products ( )

4.What crops do you grow / produce?

Crop	**Farm size**	**Quantity harvested**	**Use**		**Cost per unit**
			Subsistence	**Commercial**	
Maize					
Beans					
Sugarcane					
Bananas					
Others specify					

5. What additional tasks or pursuits are you involved in apart from farming crops? (Please tick as applicable)

Activity	**Income per month**
Brick making	
Bodaboda business	
Daily production	
Others (please specify	

6. What is your usual method of land preparation for cultivation? Please tick as appropriate)

1) Slash & burn ( )
2) Animal drawn power ( )
3) Manual tillage ( )
4) Others (specify) ……………………………………………………..

7. How do you do your cropping?

1) Mixed cropping ( )
2) Mono cropping ( )

8. Which measures do you apply to control soil erosion?

1) Crop rotation ( )
2) Mulching ( )
3) Agro-forestry ( )
4) Inter-cropping ( )

9. What methods do you use to maintain or enhance soil nutrients on your farm? Tick as applicable

a) Animal manure ( )

b) Poultry manure ( )

c) Green manure ( )

d) None ( )

Others (specify)………………………………………………………………

10. Do you receive any information or assistance from agricultural extension services regarding crop production?

a) Yes ( )

b) No ( )

11. How would you evaluate the accessibility of agricultural extension services that provide knowledge and training on crop and livestock production in your local community?

5- Highly available ( )

4- Available ( )

3- Moderately available ( )

2- Not available ( )

1- Don't know ( )

12. How do you obtain land for farming purposes? (Tick where applicable).

1) Own/private land ( )
2) Rent ( )
3) Use land near wetland ( )

3. COMMUNITY KNOWLEDGE ON THE WETLANDS

1. Can you list some of the plant and animal species that are present in the Nyangongo Wetland?

a) Plants

Name	**Use / importance**	**Current status**		
		Abundant	**Rare**	**Extinct**

b) Mammals

Name	**Use / importance**	**Current status**		
		Abundant	**Rare**	**Extinct**

c) Birds

Name	Use / importance	Current status		
		Abundant	**Rare**	**Extinct**

4. BIODIVERSITY RICHNESS AND CHANGES

1. Do you usually plant trees in your farm?

1) Yes ( )

2) No ( )

2. Mention the types of plants you have planted ?

Plant species	Numbers

3. Which trees do you like planting more? Mention them.

……………………………………………………………………………………………

……………………………………………………………………………………………

4. Give a reason for you answer in 3 above

……………………………………………………………………………………………

……………………………………………………………………………………………

5) What changes do you think have happened in the following situations as it relates to past and present times?

Situation	**Past (10-20 years)**	**Present**	**Reason**
Size of the wetland			
Crop yield			
Water quality			
Soil fertility			
Grazing area			
Type of crop grown			
Rainfall			
Rivers			
Population			

Others (specify) ……………………………………………………………………

5. EMERGING ISSUES FROM NYANGONGO WETLAND

1. What are the problems experienced by people who live around and engage in various activities in Nyangongo wetland?

Problems

Water related diseases (malaria, typhoid)

Floods

Others (specify) ……………………………………………………………………

6. CONSERVATION AND SUSTAINABLE USE OF NYANGONGO WETLAND

1. According to your opinion, do you think there is need to conserve Nyangongo wetland?

1) Yes ( )
2) No ( )

2. Who do you think is responsible for the conservation of Nyangongo wetland?

1) Government ( )
2) Local community ( )
3) Both ( )
4) Don't know ( )

3. Do you get any training from the government or any other body on wetland conservation?

1) a) Yes ( )
2) b) No ( )

If yes, please give some of these organizations

……………………………………………………………………………………………

……………………………………………………………………………………………

4. Are you aware of any wetland policies governing utilization, conservation and management of wetlands?

a) Yes ( )

b) No ( )

5. Do you usually follow the guidelines governing utilization and conservation of wetlands?

1) Yes ( )

2) No ( )

If no, Please explain why? ……………………………………………………….

………………………………………………………………………………………..

6. Is there any indigenous knowledge you apply in relation to utilization and conservation of Nyangongo wetland?

1) a) Yes ( )

2) b) No ( )

7. If your answer is yes in 6 above, state some of the methods you apply……………………………………………………………………………….

………………………………………………………………………………………

………………………………………………………………………………………

8. How do you suggest involving the local community in the planning, utilization, and conservation of Nyangongo wetland?………………………………………………………………………………

………………………………………………………………………………………

9. Tick the applicable organization operating in your location and state their roles

Organization	**Role**
NEMA	
KARI	
Ministry of Agriculture	

Others (specify)…………………………………………………………

THANK YOU VERY MUCH FOR YOUR TIME

Appendix II: Interview Guide for the Government, NGO and Private Sector Respondents.

1. For how long have you lived and worked in Kisii County?

2. Are you aware of any environmental challenges evident in Kisii County as pertains to wetland ecosystems?

1) Yes ( )
2) No ( )

3. Please rate the extent to which the following environmental challenges have led to degradation of Nyangongo wetland?

Activity	**Very large extent**	**Large extent**	**Neutral**	**Little extent**	**No extent**
Soil erosion					
Destruction of water catchment areas					
Afforestation / deforestation					
Drought					

4. To what extent can you rate the driving forces listed below contributed to encroachment of Nyangongo wetland?

Activity	**Very large extent**	**Large extent**	**Neutral**	**Little extent**
Commercialization of agricultural products				
Unemployment/poverty				
Loss of upland soil fertility				
Population growth				
Lack of land for development				

5. In your opinion what measures are being undertaken to address these challenges which have led to wetland degradation in these County?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

6. Who do you think is responsible for management and conservation of Nyangongo wetland in particular?

1) Government ( )
2) Local community ( )

7. Do you carry out any monitoring of socio-economic activities being practiced in and around Nyangongo wetland to determine their impacts?

1) Yes ( )
2) No ( )

8. If your answer in question (7) above is yes, how often do you do it?

1) Daily ( )
2) Monthly ( )
3) After every three months ( )
4) None ( )

9. In your opinion do you think it is necessary to involve the local community in planning and conservation of wetlands?

5- Strongly agree 4-Agree 3- Neutral 2- Disagree 1- Strongly disagree

10. What challenges do you encounter when engaging the community members in matters to deal with environmental conservation?

…………………………………………………………………………………………

………………………………………………………………………………………….

11. Do you offer any training to local community on matters of wetland utilization and conservation?

1) Yes ( )
2) No ( )

12. Do you have guidelines and policies in place for wetland utilization, conservation and management?

a) Yes b) No

13. If your answer in (12) above is yes, are these policies being implemented to avert any unsustainable practices in and around wetlands?

a) Yes b) No

14. What scientific / modern approaches to environmental conservation and in particular wetlands are currently being applied in Kisii County?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

15. Do you normally make reference to indigenous knowledge on the need to conserve wetland ecosystems? Please explain.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

16. Do you think it is necessary to integrate indigenous knowledge with modern scientific management approach to aid in wetland utilization and conservation?

1) Yes 2) No

If your answer is yes please explain how it can be done.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

17. Has the national government or county government provided enough funds to aid in wetland management and conservation?

1) Yes ( )
2) No ( )

18. How often are you involved in meetings on environmental issues with other stakeholders in Kisii County?

1) Daily ( )
2) Weekly ( )
3) Quarterly ( )
4) None ( )

19. Do you think there are emerging issues that have led to wetland degradation in Kisii County? Explain your answer.

…………………………………………………………………………………………

…………………………………………………………………………………………

20. To what extent has the factor listed below led to degradation of Nyangongo wetland?

Scale 5 – very large extent 4 – large extent 3- neutral 2- little extent 1- No extent

Activity	**Very large extent**	**Large extent**	**Neutral**	**Little extent**
Crop production				
Settlement				
Woodlot				
Brick making				

Cattle grazing				
Aquaculture				
Institutional development				
Other (specify)				

THANK YOU

Appendix III: Focused Group Interview Guide (FGD)

1. Do people in this area have sufficient land to enable them meet their socio-economic needs? 1) Yes ( ) 2) No ( )

2. If No in 1 above, what do they do to cope with the situation?

   1) a) Rent land ( )
   2) b) Rent wetland for agricultural activities ( )
   3) Engage in business. ( )

3. What do you think are the driving factors that have forced people to encroach the wetland?

   1) Loss of upland soil fertility ( )
   2) Fertile and moist conditions on wetland. ( )
   3) Decline in upland size due to population ( )
   4) Lack of employment for the youths ( )
   5) Ready market for cash crops grown on wetland ( )

4. What are the main economic activities people engage themselves on the wetland?

   1) Agriculture ( ) 2) Brick making ( )

   3) Timber production ( ) 4) Aquaculture ( )

5. What are the main crops grown in/ around the wetland?

   1) Sugarcane ( ) 2) Banana ( ) 3) Maize ( ) 4) Tea( )

Others specify…………………………………………………………………………

6. What is the most commonly used method of land preparation on wetland

   1) Hand hoeing ( ) 2) ox plowing ( ) 3) Tractors ( )

Others specify…………………………………………………………………………

7. Do farmers in this area use fertilizers to enhance crop production?

   2) Yes ( ) 2) No ( )

If yes, which type of fertilizer do they commonly use?

2) Organic fertilizers ( ) 2) Inorganic fertilizers ( )

8. Have you ever experienced conflict on wetland resource utilization in this are?

1) Yes ( ) 2) No ( )

9. If Yes, What were the reasons for the conflict?

………………………………………………………………………………………

10. Do you think cultivation on wetland generates high yields as compared to upland cultivation? 1) Yes ( ) 1) No ( )

11. How will you rate wetland crop production in this area?

1) Very high ( ) 2) not so high ( ) 3) Don't know. ( )

12. What would you comment on the size of this wetland as it is currently compared with its size in the last 20 years?

1) Increased ( ) 2) Decreased ( ) 3) Don't know( ) 4) No changes ( )

13. Thirty years ago, was there any activity that was being carried out in this wetland?

2) Yes ( ) 2) No ( )

14. How would you describe the trends in wetland utilization for the last 30 years?

1) Uses have increased slightly ( ) 2) Uses have increased tremendously ( )

3) Uses have remained the same ( ) 4) I don't know. ( )

15. How would you compare the current vegetation cover/ natural state of the wetland to that of 1980s? 1) Has increased / improved ( ) 2) has decreased / declined ( ) 3) No change ( ) 4) Don't know ( )

16. Are there any management plans in this area with regard to wetland resource utilization 1) Yes ( ) 2) No. ( )

17. If No, what would you say should be the number one undertaking/ consideration for the future of this wetland?

1) Drained further ( ) 2) Be left alone to recover ( )

3) A land use plan developed to balance human and environmental needs ( )

Others specify …………………………………………………………………………

17. Have you ever been directed / trained by the government on wise use strategies for this wetland? 1) Yes ( ) 2) No ( )

18. What do you think the government should do with regard to wetland resource management?

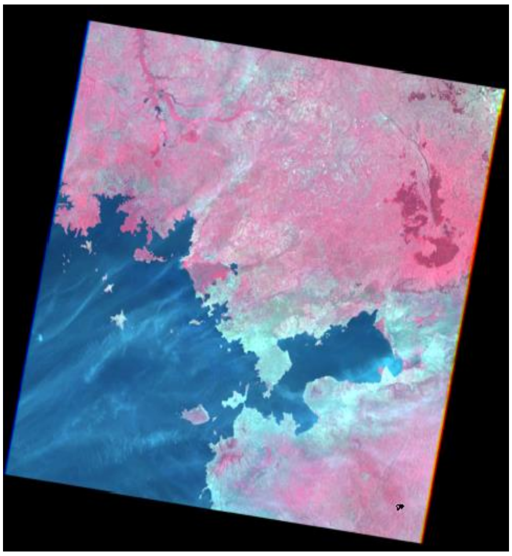
1) Evacuate people from wetland. ( )
2) Promote sustainable use through participatory management planning ( )
3) Should not interfere with it. ( )
4) Others specify………………………………………………………

Appendix IV: Observation Schedule

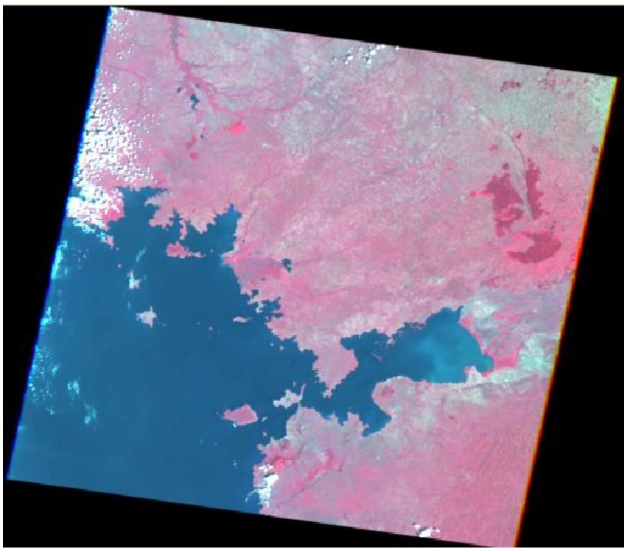
Observable parameter	**Date**	**Area**	**Variables**	**Remarks/commence**
Vegetation Thatch grass Palm trees Crotria axillaris Acacia meamsii Solanum incunum Omobeno Rise Blue gum		**Planted on:** river banksprings upland area	Mat, basket making Fooder, vegetable Fuel wood Medicinal Medicinal Medicinal Fuel wood, timber	
Water sources			SpringBore hole Tank/rain	
Crops cultivated			Sugarcane Maize Tea Bananas Finger millet Beans	
Grazing			Indigenous	

			Hybrid Zero grazing Paddocking Free ranch Tethering Number	
Water quality			Greenish/algae Turbid Clear	
Water points quantity			High flow Low flow	
River regime			soil erosion silted	
Birds			Grey crowned crane Herons	
Wetland drainage			Terraces	
Plot size				

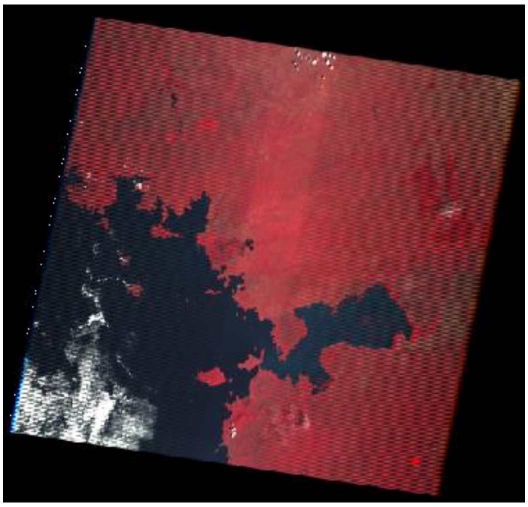
Appendix V: Land Sat Images



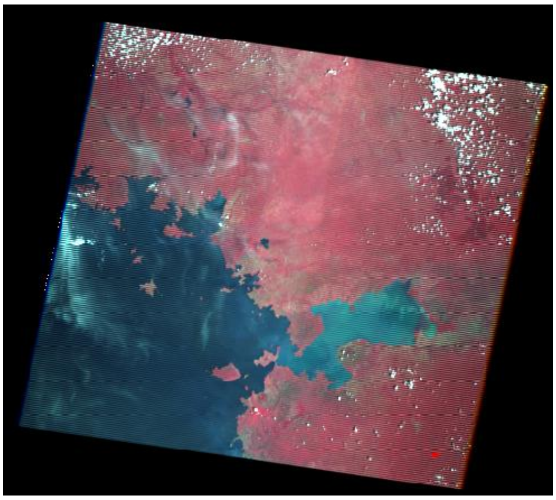
1984 Landsat image



1994 Landsat Image



2004 Landsat Image



2021 Landsat Image

Appendix VI: Research Permit

THIS IS TO CERTIFY THAT:
MR. BENNETON ONDENGI OGECHI
of UNIVERSITY OF ELDORET, 3900-30100 ELDORET,has been permitted to conduct research in *Kisii County*

on the topic: *IMPACT OF LAND USE PRACTICES ON WETLAND ECOSYSTEM IN KENYA. THE CASE OF NYANGONGO WETLAND IN NYARIBARI CHACHE SUB-COUNTY IN KISII.*

for the period ending:
25th July,2018

Permit No : NACOSTI/P/17/16399/16852
Date Of Issue : 26th July,2017
Fee Recieved :Ksh 1000

Applicant's Signature

Director General
National Commission for Science, Technology & Innovation

CONDITIONS

1. **The License is valid for the proposed research, research site specified period.**
2. **Both the Licence and any rights thereunder are non-transferable.**
3. **Upon request of the Commission, the Licensee shall submit a progress report.**
4. **The Licensee shall report to the County Director of Education and County Governor in the area of research before commencement of the research.**
5. **Excavation, filming and collection of specimens are subject to further permissions from relevant Government agencies.**
6. **This Licence does not give authority to transfer research materials.**
7. **The Licensee shall submit two (2) hard copies and upload a soft copy of their final report.**
8. **The Commission reserves the right to modify the conditions of this Licence including its cancellation without prior notice.**

REPUBLIC OF KENYA

NACOSTI

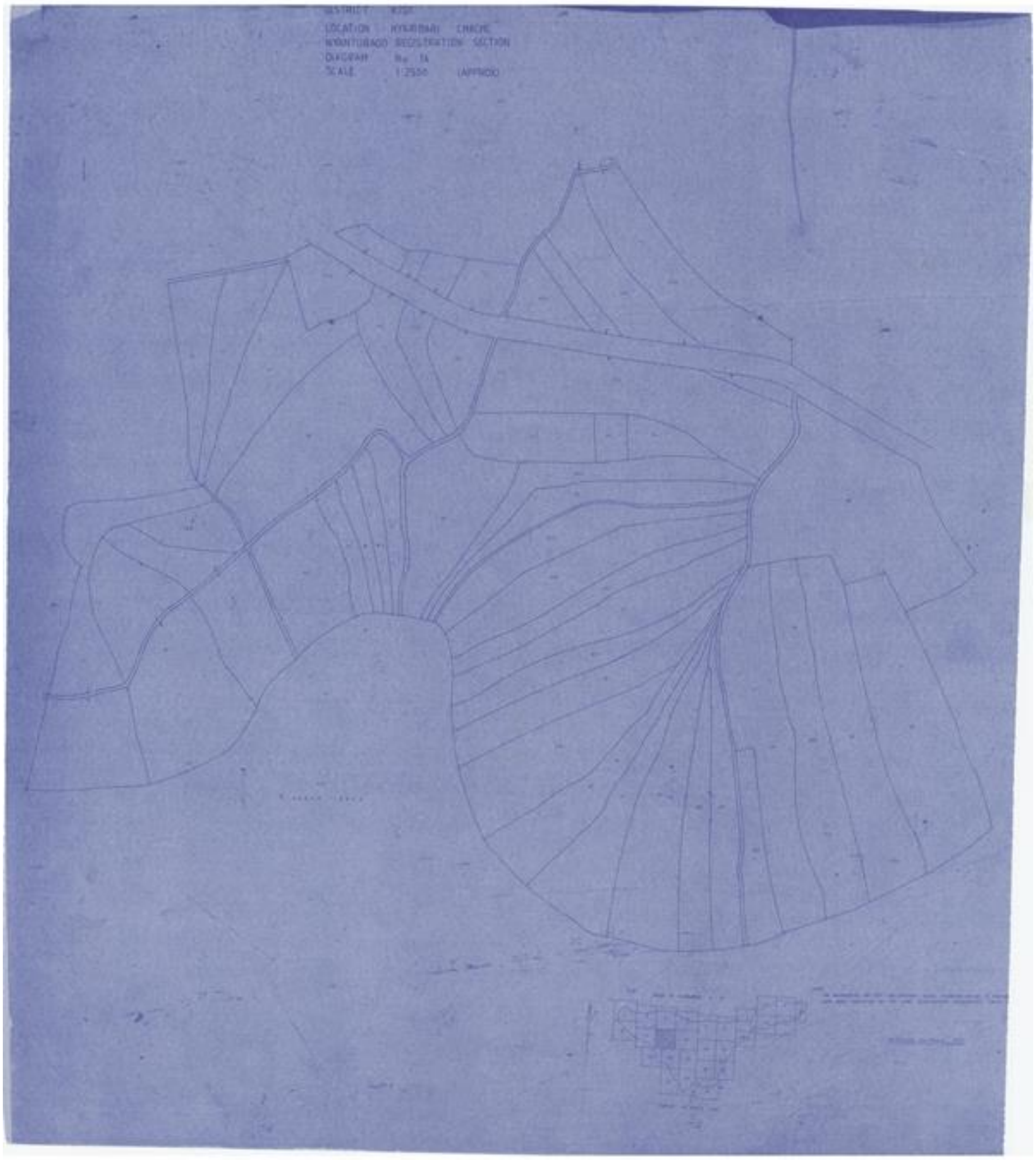
National Commission for Science, Technology and Innovation

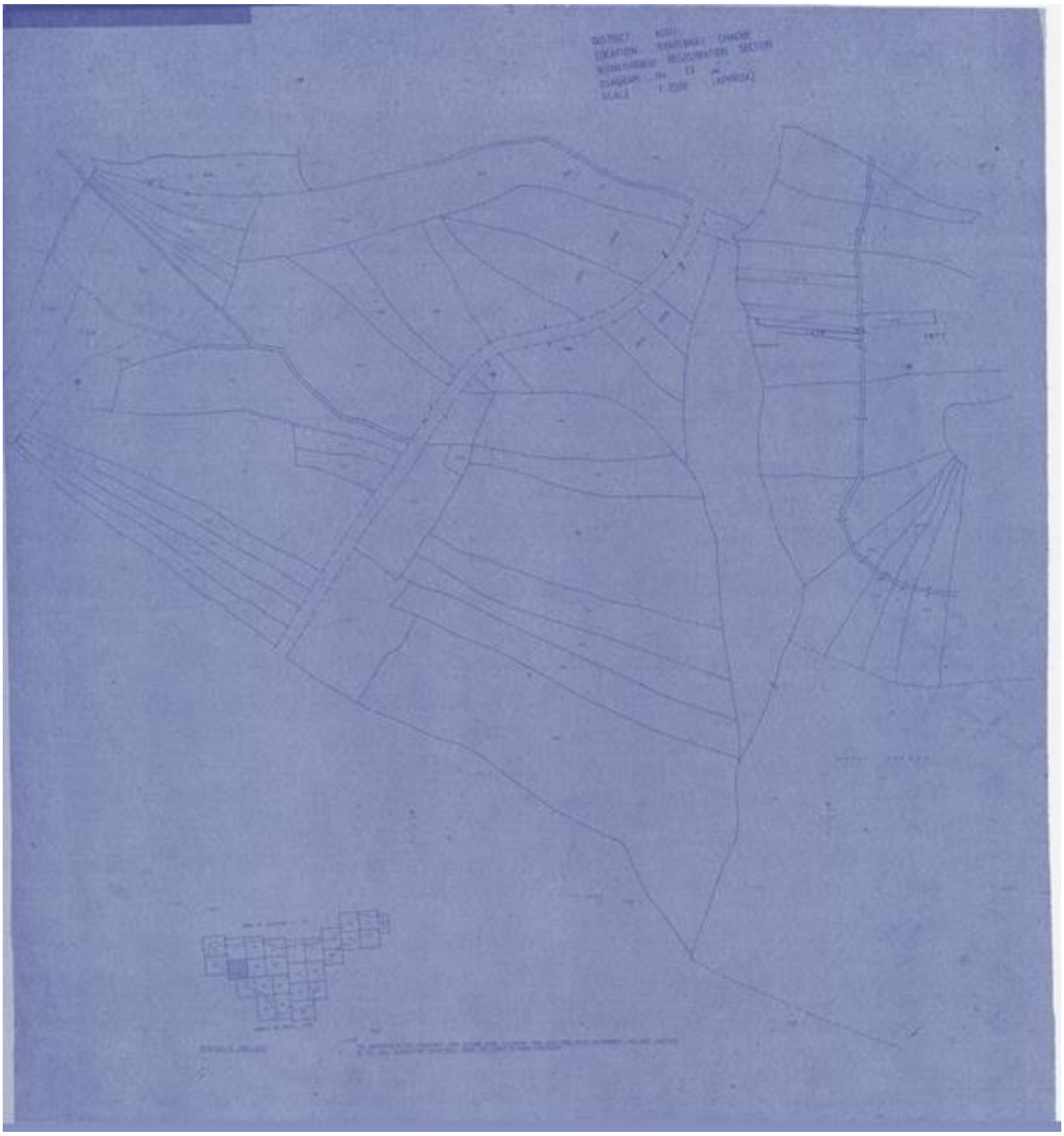
RESEARCH CLEARANCE PERMIT

Serial No.A 15114

CONDITIONS: see back page

Appendix VII: Preliminary Index Diagrams

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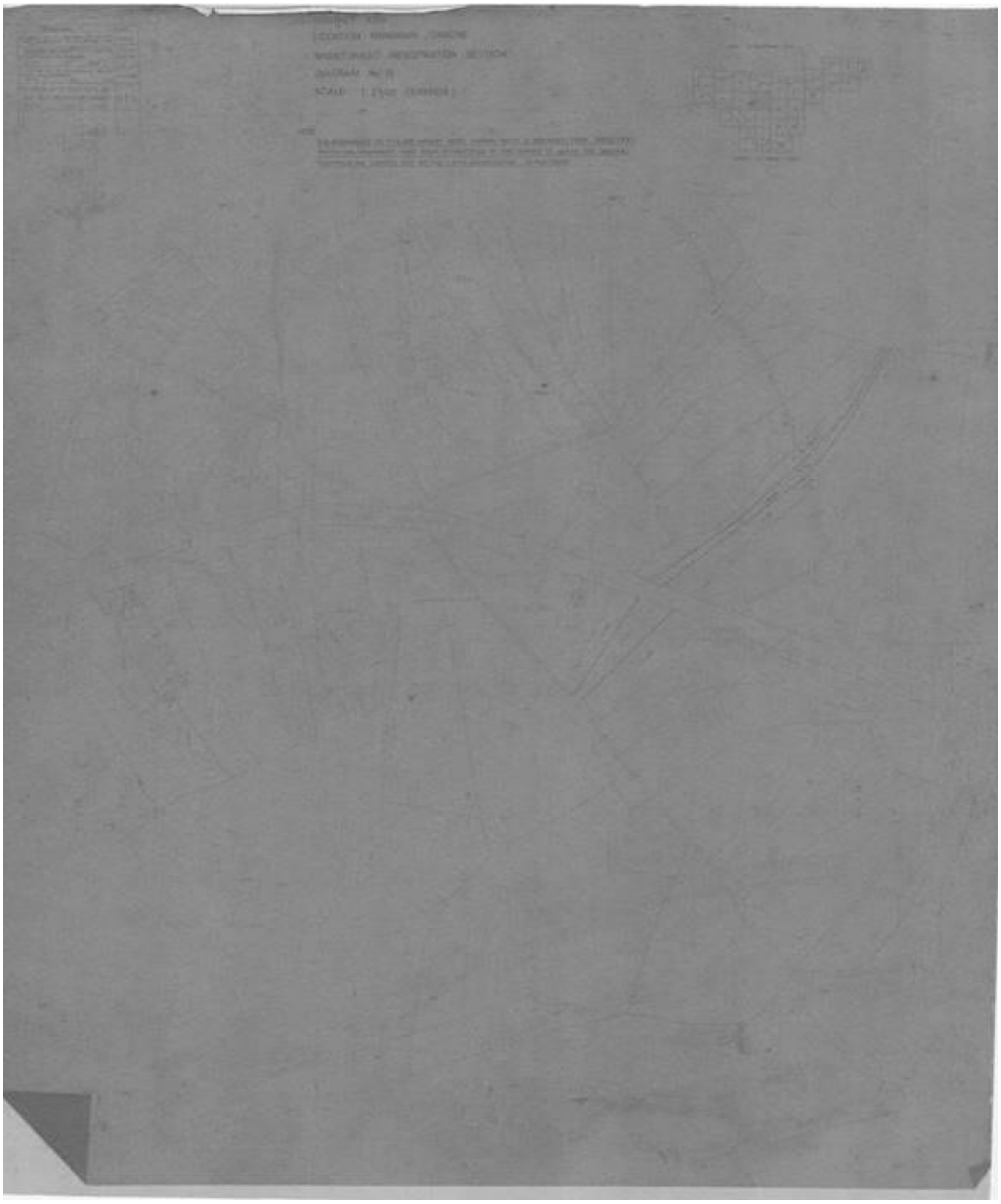
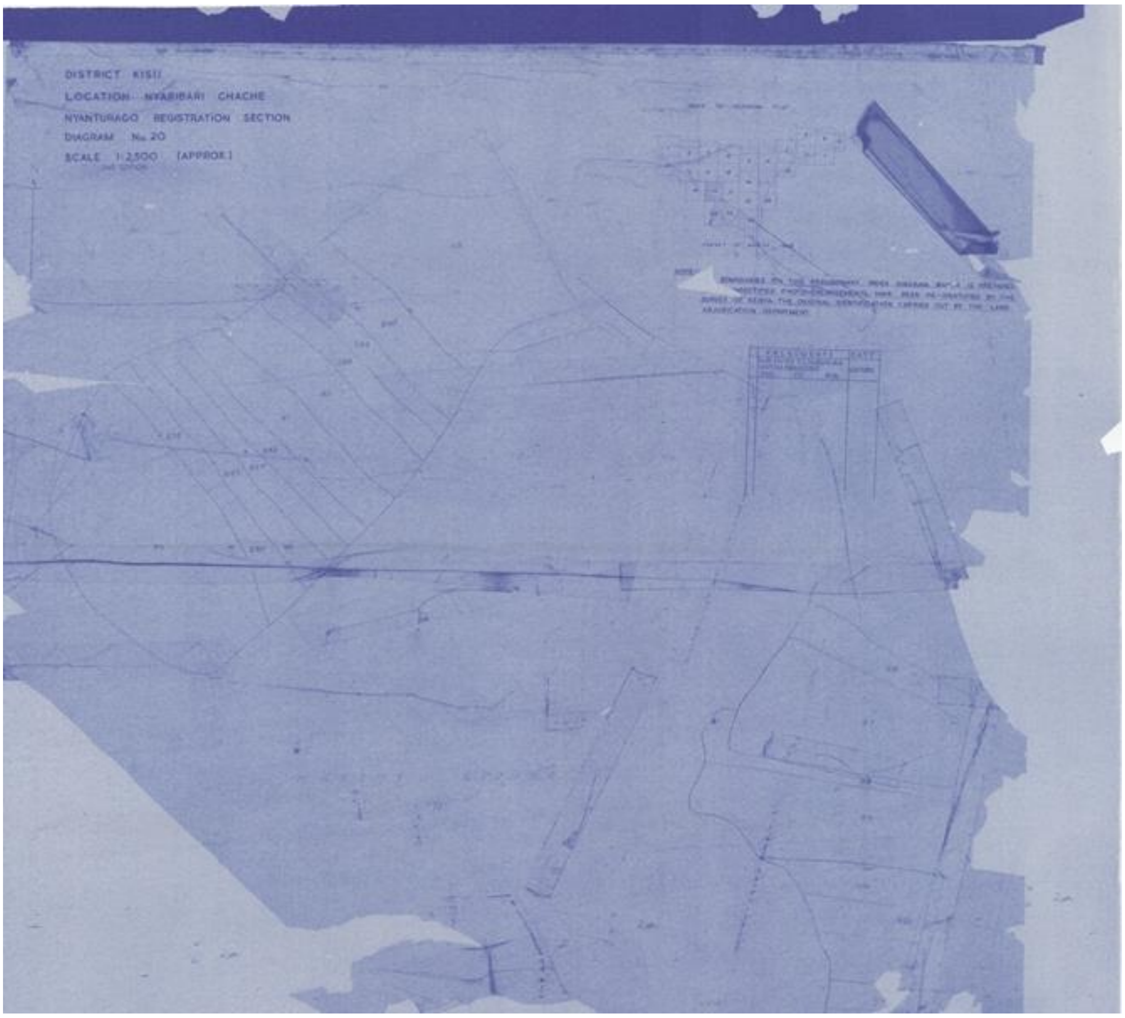
LOCATION
SCALE

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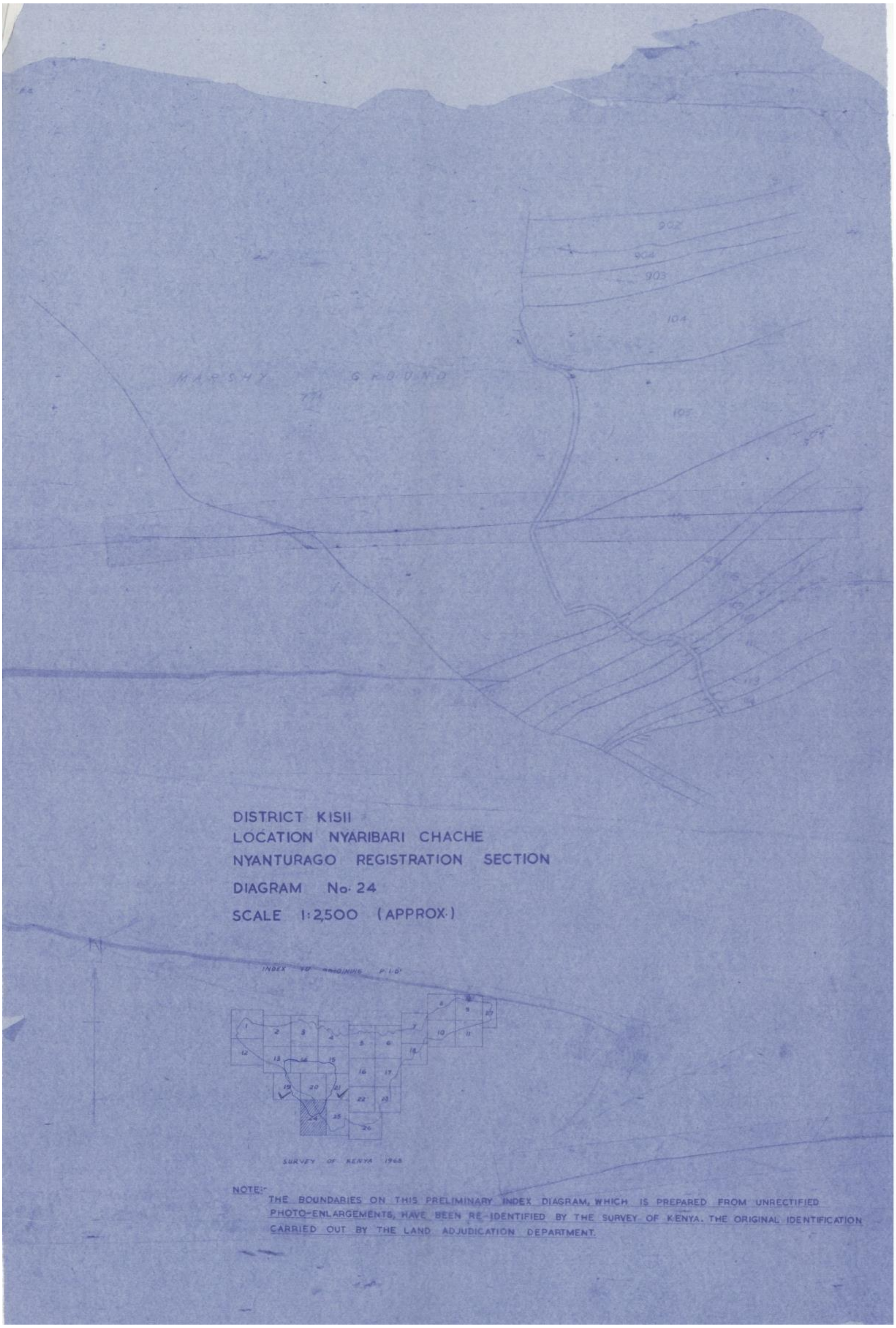
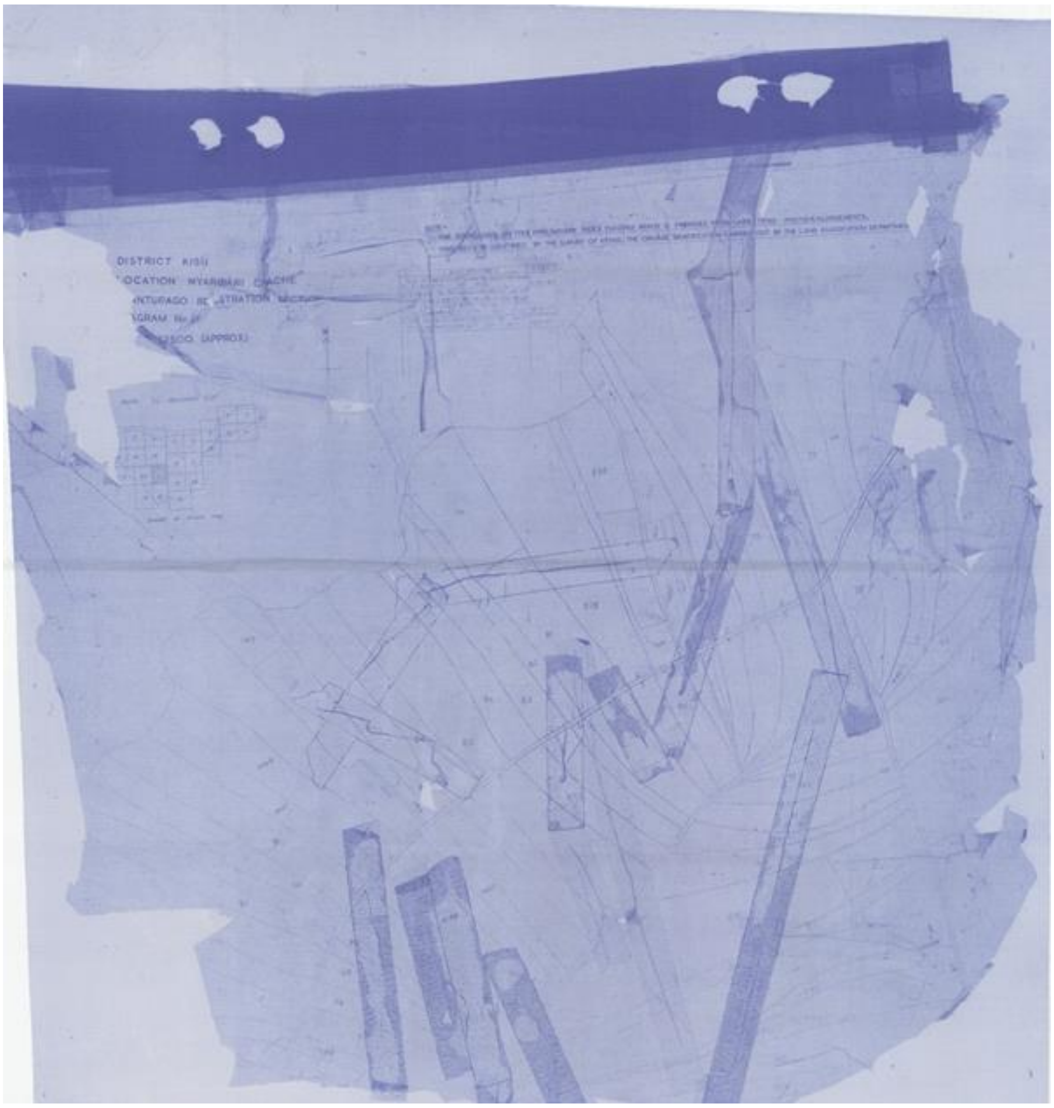
LOCATION NYARIBARI CHACHE
NYANTURAGO REGISTRATION SECTION
DIAGRAM No. 20
SCALE 1:2,500 (APPROX.)


MARSHY GROUND
DISTRICT KISII
LOCATION NYARIBARI CHACHE
NYANTURAGO REGISTRATION SECTION
DIAGRAM No. 24
SCALE 1:2,500 (APPROX.)
SURVEY OF KENYA 1968
NOTE:- THE BOUNDARIES ON THIS PRELIMINARY INDEX DIAGRAM, WHICH IS PREPARED FROM UNRECTIFIED PHOTO-ENLARGEMENTS, HAVE BEEN RE-IDENTIFIED BY THE SURVEY OF KENYA. THE ORIGINAL IDENTIFICATION CARRIED OUT BY THE LAND ADJUDICATION DEPARTMENT.


DISTRICT KISII
OCATION NYARIBARI CHACHE
(APPROX)

Appendix VIII: Similarity Report

University of Eldoret

Certificate of Plagiarism Check for Synopsis

Author Name	Benneton Ondeng'i Ogechi SES/PGPM/013/15
Course of Study	Type here...
Name of Guide	Type here...
Department	Type here...
Acceptable Maximum Limit	Type here...
Submitted By	titustoo@uoeld.ac.ke
Paper Title	INFLUENCE OF ANTHROPOGENIC ACTIVITIES ON NYANGONGO WETLAND IN NYARIBARI CHACHE SUB-COUNTY, KISII COUNTY-KENYA
Similarity	8%
Paper ID	994602
Submission Date	2023-10-02 14:59:56

Signature of Student

Signature of Guide

Head of the Department

* This report has been generated by DrillBit Anti-Plagiarism Software