THE ECOLOGY AND LIVELIHOODS OF THE LOCAL COMMUNITY IN OMBEYI WETLAND - NYANDO SUB COUNTY, KENYA

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A Thesis Submitted to the Board of Postgraduate Studies in Partial Fulfillment of the Requirements for the Award of the Degree of Master of Science in Natural Resources Management of Egerton University

EGERTON UNIVERSITY

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DECLARATION AND RECOMMENDATION

DECLARATION

I hereby declare that this thesis is my original work and has not been presented for the award of degree at Egerton University or any other University and that all the sources used herein have been acknowledged.

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NM11/375

Signature …………………………… Date ………………………

RECOMMENDATION

This thesis has been submitted for examination with our approval as University Supervisors.

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DEDICATION

This thesis is dedicated to my parents Mr. Barrack Obodi and Mrs. Evaline Obodi who bequeathed vital life skills and who not only supported me, but also enlivened me to appreciate the astronomic value of education at a very tender age. Thank you.

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ABSTRACT

Wetlands cover about 4–6% of the earth's surface and are the most productive ecosystems on earth. However, they are under threat from natural and anthropogenic factors with more than half having disappeared, largely through factors related to increase in human population such as; conversion to agricultural use, urbanization, transport and communication, human settlement and infrastructure expansion. This study assessed water quality, vegetation status, socio-economic status as well as livelihood options of local communities adjacent to Ombeyi wetland, Kenya. Water quality (pH, Dissolved Oxygen (DO) and turbidity) were obtained from nine sites within the wetland. Vegetation attributes; species composition and frequency were assessed using ecological data collection techniques involving random quadrat method. A questionnaire was used to assess the socio-economic activities as well as livelihood options among the local communities. Data was analyzed using descriptive and inferential statistics tests.

The findings indicate variations in mean values of select physico-chemical characteristics at various sites in the wetland. There was significant site effect on mean water turbidity ($F_{1,8.}$ =29.95, P<0.01) pH ($F_{1,8.}$ =8.13, P<0.01), Dissolved Oxygen ($F_{1,8.}$ =5.19, P<0.01) with the high turbidity values being observed at site S7 (129±8.5 NTUs) and low turbidity values at S1 (82.7±1.33 NTUs). pH ranged from 6.7±0.21 to 7.9±0.46 in sites S1 and S6 respectively. The low values of dissolved oxygen were recorded at site S6 (6.2±0.16mgL^{-1}). Fifteen plant species were encountered in the wetland and vegetation varied in composition amongst sites with sites S2 and S4 recording the high numbers and site S9 recording low numbers of species. The three abundant plant species were Centella asiatica, Pycreus nitidus and Trifolium vesiculosum. Cyperus papyrus was observed to have been exploited in many areas within the wetland. The most common activity practiced by the community was fishing and cattle grazing, which had a negative correlation with the water pH, dissolved oxygen (DO) and turbidity. This high level of dependence on farming and grazing is likely to have contributed to the general decline of wetland vegetation.

These findings will contribute towards improvement of policy implementation and awareness creation on the need to protect the wetland through sustainable exploitation of wetland vegetation and natural resources.

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LIST OF ACRONYMS AND ABBREVIATIONS

IUCN	International Union for Conservation of Nature
LVEMP	Lake Victoria Environmental Management Project
SDGs	Sustainable Development Goals
HIV	Human Immunodeficiency Virus
AIDS	Acquired Immune Deficiency Syndrome
KEFRI	Kenya Forestry Research Institute
DO	Dissolved Oxygen
TSS	Total Suspended Solids
NEMA	National Environment Management Authority
WHO	World health Organization
DECD	Digital Expandable Color Display
DPSIR	Drivers, Pressures, States, Impacts and Responses
CO2	Carbon Dioxide
BOD	Biological Oxygen Demand
COD	Carbon Oxygen Demand
pH	A figure expressing the acidity or alkalinity of a solution on a logarithmic scale
NTUs	Nephelometric Turbidity Unit
ANOVA	Analysis of Variance
SPSS	Statistical Package for the Social Sciences
TDS	Total Dissolved Solids
EMCA	Environmental Management and Coordination Act
WRMA	Water Resources Management Authority
IWWM	Integrated Wetland-Watershed Management
LVB	Lake Victoria Basin
SEA	Strategic Environmental Assessment
LUP	Land Use Plan

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Wetland ecosystems are the most diverse and productive ecosystems on earth and include marshes, lakes, rivers, flood basins, estuarine deltas, ponds, rice fields, and marine water areas where the depth at low tide does not exceed 6 m (Convention on Wetlands 1971). Wetlands cover 4–6% of the earth's surface and are considered to be one of the most productive ecosystems on earth's surface (Wetlands International Africa, 2009). However, wetland ecosystems are also among the most threatened (Abebe, 2003) with more than 50% of the world's wetlands altered, degraded, or lost in the last 150 years (O'Connell 2003). The global review of wetland resources and priorities for wetland inventory in 1999 found that only 7% of all countries had adequate national wetland inventories and 25% had no available national wetland inventory (Conference of Parties, 2002; Revenga, 2003). More than 54% wetlands had been lost by the mid-1980s, primarily to agriculture and industrialization in the United States (Gibbs, 2000). Foote et al. (1996) described how an increasing rural population in India places enormous pressure on natural wetlands and described 12 major causes of wetland loss in that country, agriculture again dominating as the primary cause.

Many wetlands in Eastern Africa have come under extreme pressure as government policies; socio-economic hinge and population increase have stimulated a need for more agriculturally productive and urban land (Van Dam, 2011). In Nakivubo wetland in Kampala approximately US$ 100,000 was estimated to accrue from wetland goods and products through crop cultivation, papyrus harvesting, brick making, and fish farming (Kaggwa et al, 2009). In rural areas of Uganda, households engaged in papyrus harvesting are estimated to be deriving as much as US$ 200 a year from their wetland activities and approximately five million people depend directly on wetlands for their water supply (Kansiime et al, 2007). Kenya's wetlands occupy around 3-4% of Kenya's land mass though this can momentarily rocket to 6% in the rainy seasons (Kenya Wetlands Forum, 2012). The wetlands continue to face a myriad of challenges including reclamation and encroachment for agriculture, settlement and industrial development; invasive and alien species; pollution and eutrophication due to population pressure (Raburu, 2003).

The Ombeyi wetland ecosystem is an important wetland contributing to the natural capital in Kenya's side of the Lake Victoria Basin. It provides essential benefits to local communities who directly and indirectly depend on it for their livelihood support and income (Orwa et al., 2012). Directly, the wetland is used for fishing, hunting, sand and clay extraction for construction and pottery respectively. It further provides water for household and industrial uses, small-scale agriculture for both subsistence and commercial purposes in addition to papyrus and other reeds (wetland grasses) for roofing and livestock grazing among others. It acts as a home for many plants and wildlife, providing conducive breeding and feeding areas for diverse animals. Indirectly, it recharges the underground water aquifers and enhances environmental flows in other wetlands connected with it, regulates flood flow regimes and act as important stabilizers for maintaining micro-climate (Raburu, 2003).

Inspite of the many benefits and services that Ombeyi wetland provides, land use changes, poverty, coupled with rapid socio-economic dynamics of increasing population, HIV/AIDS, inequity and lack of an elaborate planning framework have impeded the sustainable management and development of the Ombeyi Ecosystem for both present and future generations (Orwa et al., 2012). This has resulted in degradation, water pollution, loss of biodiversity leading to loss of livelihoods

Land use changes are important drivers of water, soil and air pollution. The oldest form being land clearance for agriculture and harvest of trees and other biomass which leaves soils vulnerable to massive increase in soil erosion by wind and water (Erle and Pontius, 2007) Modern agricultural practices, which include, intensive inputs of nitrogen and phosphorus fertilizers have substantially increased the pollution of surface water by runoff and erosion and the pollution of groundwater by leaching of excess nitrogen (as nitrate) (Hunt, 2004). Other agricultural chemicals; including herbicides and pesticides are also released to ground and surface waters by agriculture and in some cases remain as contaminants.

The major sources of water in a wetland are determined by its geomorphic setting and local climatic conditions. In turn, the sources of the water in a wetland determine not only the amount present and when it is present, but also its chemistry. The water chemistry of wetlands whose primary source of water is precipitation will be very different from that of a wetland whose primary source of water is groundwater discharge. This can have a major effect on the species composition of the vegetation and its primary production (Scheren et al., 2000).

The loss of wetland ecosystem services damages the health and well-being of individuals and local communities and diminishes their development prospects (Millennium Ecosystem Assessment 2005). This problem is of serious concern in many countries where local communities are highly dependent on wetland resources. It is particularly severe in countries that have weak policy and management strategies, negatively affecting the conservation and sustainable management of wetland resources. Decline in resources for instance fish in the wetland forces fishing communities to consider alternate livelihood measures such as poultry, livestock and crop farming, handicrafts, and nonfarm day labor (Rahman et al. 2012). Thus the study carried out an ecological assessment of Ombeyi wetland and livelihood dynamics of the adjacent dependent communities in order to identify the status of the wetland.

1.2 The Statement of the Problem

Despite their importance, wetlands are being modified or reclaimed, often driven by economic and financial motives. Wetlands, however, contain numerous goods and services that have an economic value not only to local populations but also to people living outside the periphery of the wetland. The low economic status of Nyando Sub-County with a poverty prevalence of 63% has augmented the drive to exploit Ombeyi wetland (LVEMP). There is increased human settlements leading to overharvesting of the wetland resources (both animal and plant resources) and increase in pollution levels (LVEMP). This has resulted to loss of biodiversity, declining water quantities from degraded wetlands and loss of people’s livelihoods.

Wetlands are currently degraded by both natural and anthropogenic activities, which deteriorate their quality, and push them to the brink of extinction in the process of unplanned development, giving rise to the need for suitable conservation strategies. Unfortunately, over the years, less attention has been given to wetland losses world over, including Ombeyi. The degradation of Ombeyi wetland has altered its functions, affecting the ecological balance and resulting in economic consequences for the local people. This study aimed at investigating the ecology and livelihoods of the local community in Ombeyi Wetland.

1.3 Objectives of the Study

1.3.1. Broad Objective

To contribute to sustainable management and conservation of Ombeyi wetland and hence ensure sustained provisioning of ecosystem services and goods necessary to sustain local livelihoods.

1.3.2. Specific Objectives

The specific objectives of the study were:

1. To compare the water quality parameters (Dissolved Oxygen, pH and Turbidity) at different points in Ombeyi wetland
2. To assess the vegetation structure and composition in Ombeyi wetland
3. To characterize the socio economic factors and livelihoods of the communities dependent on Ombeyi wetland

1.4 Research Questions

1. Are the water quality parameters (Dissolved Oxygen, pH and Turbidity) different across sites?
2. What is the composition of wetland vegetation in Ombeyi wetland?
3. What is the socio-economic status of local dependent communities at Ombeyi wetlands?
4. What livelihoods options exist on Ombeyi wetland?

1.5 Justification of the Study

Generally, wetland functions directly relate to their physical, chemical and biological integrity. Water quality evaluation for wetlands leads to information about their misuse by indicating the pollution status. Gale et al. (1993) define water quality objectives as the overall direction and purpose of the project, and furthermore define goals as milestones to be met during the course of a project. Since the quality of aquatic life depends on the water quality, a thorough assessment of the water quality was an integral part of Ombeyi wetland evaluation, thus the comparison of the water quality parameters (pH, Turbidity and Dissolved Oxygen) at different points in the wetland.

The findings from the study would provide information on the ecological status of the Ombeyi wetland and ways of improving the economic and ecological services provided by this system. The SDG 6 ‘Clean Water and Sanitation’ goal aims at ensuring access to clean water and sanitation for all. Other relevant SDGs to this study include: 1 - ‘No Poverty’ 3 – ‘Good Health and Well-being’ and 13 – ‘Climate Action’. Provision of water and sanitation is also one of the social strategy goals of Kenya vision 2030. Protecting and restoring water-related ecosystems such as wetlands is essential in order to mitigate water scarcity.

The findings would provide a basis for the designing of specific mitigation measures such as improved farming and irrigation systems, community awareness and provision of alternative income generating activities in future. According to the 15th SDG goal on life on land, the aim is to sustainably manage forests, combat desertification, reverse land degradation and halt biodiversity loss. Kenya aims at having clean, secure and sustainable environment as depicted by its environment goal as one of its social strategy goals. The Sustainable Development Goals (SDGs) aim to conserve and restore the use of terrestrial ecosystems such as wetlands by 2020 to reduce the loss of natural habitats and biodiversity. The findings from this study will help spearhead and sustain a wetland monitoring and assessment scheme using various methods/techniques that are compliant with the existing legislative and regulatory frameworks.

The study findings would also benefit the water resources management and fisheries sector as it helps identify the endangered species whether flora or fauna or both. The policy makers and local communities would benefit particularly on salient wetland management options as well as the cost and benefits of alternative wetland management schemes.

1.6 Scope of the Study

The study was limited to Ombeyi wetland. The ecological assessment was limited to the study of water characteristics and wetland vegetation over a period of four months. Water quality parameters studied were water turbidity, water pH and dissolved oxygen. Species included in composition measurements were those in areas inundated seasonally or permanently. The population sampled was confined to those that directly benefited from the wetland on either of the sampled sites. The household heads above the age of 18 years were used in filling the questionnaires.

There was reluctance by some of the respondents to offer information during the interviews. This was however countered by formulating focused group discussions to allow for public participation. Communication language was a barrier too because other respondents could only speak in their mother tongue, however this was countered through using translators. Vegetation identification to species level was equally a challenge and this was overcome by seeking guidance from wetland plant at Egerton University

1.7 Assumptions of the Study

The study assumed that the physical and chemical water quality was affected by human activities around the Ombeyi wetland and that vegetation composition was affected by human activities around the wetland. The study further assumed that the surrounding communities highly depended on the wetland for their daily livelihood. Additionally, the study assumed that the socio-economic and cultural aspects of the local community remained constant throughout the study period and that the political stability in the study area remained constant throughout the study period.

1.8 Definition of Terms

Indigenous knowledge: is the local understanding by a certain community with the same culture on existence of the wetland products and their usage.

Livelihood: a means of securing the necessities of life on a daily basis

Local uses: is utilization of the wetland products by the local community through consumption or selling within or outside the Ombeyi wetland.

Regeneration: is the ability to replace lost or damaged body parts and in plants it is through sprouts from cut trees.

Species diversity: refers to a combination of richness and relative abundance of a particular species.

Vegetation: is assemblages of plant species and the ground cover they provide

Wetland: is a land area that is saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct ecosystem

Macrophytes: Macrophytes are aquatic plants growing in or near water. They may be emergent, submerged or floating.

Species frequency: is the number of times a plant species is present in a given number of quadrats of a particular size or at a given number of sample points.

Species density: is a measure of the number of organisms that make up a population in a defined area

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction on Wetlands

Wetlands are ecosystems that incorporate the features of terrestrial along with aquatic environments particularly soil, water and vegetation (Copeland, 2010). They are regions of marsh, bayou, peat land or water, whether temporary or permanent, artificial or natural, with static water or flowing, fresh or salty (Lathrop, 2011). Five major wetland categories are recognized, namely marine, estuarine, lacustrine, riverine and palustrine (Wetlands International, 2009). Despite their modest geographic extent, wetlands provide a number of critical ecosystem services that are indispensable to human beings and biodiversity's very survival, health and welfare. Wetlands contribute in diverse ways to the livelihood of many people and biodiversity in Africa (Food and Agriculture Organization of the United Nations, 2008). One of the major constraints to the judicious use of African wetlands is lack of knowledge by planners and natural resource managers of the benefits that they provide and techniques by which they can be utilized in a sustainable manner (Jogo and Hassan, 2010). Consequently, owing to a lack of scientific investigation and inconsistent mapping policies in Africa, the total extent of wetlands on the continent is still unknown (Schuyt, 2005).

Wetland ecosystems, including rivers, lakes, marshes, rice fields, and coastal areas, provide many services that contribute to human well-being and poverty alleviation. Some groups of people, particularly those living near the wetlands, are highly dependent on these services and are directly harmed by their degradation (Millennium Ecosystem Assessment, 2005). Wetlands deliver a wide range of hydrological services – for instance, swamps, lakes, and marshes assist with flood mitigation, promote ground water recharge, and regular river flows – but the nature and value of these services differs across wetland types. Many wetlands diminish the destructive nature of flooding, and the loss of these wetlands increases the risks of floods occurring. Wetlands such as flood plains, lakes, and reservoirs are the main providers of flood attenuation potential in inland water systems (Co'zaret al., 2007).

Wetlands play a very significant role in sequestering carbon from the atmosphere through plant photosynthesis and also acting as sediment traps for runoff (Millennium Ecosystem Assessment, 2005). Wetlands helps in regulating exchanges to/from the atmosphere of the naturally-produced gases involved in “greenhouse” effects such as water vapour, carbon dioxide, methane, nitrous oxide and sulphur dioxide (Pritchard, 2009). The extent of storage is dependent on wetland type and size, the depth of wetland soils, vegetation, groundwater pH and nutrient levels among others (Polasky and Liu, 2006). Wetlands also release carbon both through natural, seasonal changes and, more drastically, when their equilibrium is affected by human interference (Kusler, 1999). Destruction of wetland not only means the loss of that particular carbon sink, but also that the carbon in that wetland will be released thus increasing the total carbon load levels in the atmosphere. Wetland protection and restoration measures can improve the carbon sequestration potential of wetlands though it takes several decades for the carbon sequestration ability of restored wetlands to reach levels comparable to those of natural wetlands (Blanca &Mitsch, 2012).

Wetlands are used by a host of different species which either exploits them throughout the year (resident species) or for only part of the year (migrant and nomadic species). Thus, wetland sites whether at a local scale or at a global or flyway scale form important habitat chains for waterbirds such as swans, terns, coots, grebes, cormorants, and ducks among others which are mobile and able to use a variety of different sites through the year. The amount of usage, and by how many species and individuals, can vary depending on environmental conditions (Lake Victoria Basin Commission, 2011). The principle supply of renewable fresh water for human use comes from an array of inland wetlands, including lakes, rivers, swamps, and swallows ground water aquifers (Balirwa, 2007). Groundwater, often recharged through wetlands, plays an important role in water supply, with an estimated 1.5-3 billion people dependent on it as a source of drinking water (Co'zar et al., 2007).

Wetlands, and in particular marshes, play a major role in treating and detoxifying a variety of waste products. Some wetlands have been found to reduce the concentration of nitrate by more than 80% (Quinn, 2009). Wetlands also provide a vitally important, water treatment and purification (Millennium Ecosystem Assessment, 2005). The waste include: detergents, pesticides, oil, acids, nitrates, phosphates and heavy metals. The wetlands treat and purify this water before it is passed onto the lake or connecting river (National Environment Management Authority, 2007). Most urban populations in Uganda lack water-borne sewage systems and domestic wastes often flow directly into swamps and wetlands (Kansiime et al., 2007).

Despite their ecological importance, wetlands are not well characterized (John and Laura, 2004) and adequately appreciated for the services they provide. The main anthropogenic stressors of wetlands are drainage, dredging, filling, tillage, construction, discharge, mining and abstraction (Abebe, 2003). For instance, overexploitation of wetland resources such as water, food and raw materials that sustain the livelihoods of significant populations are under great pressure, as can be seen at lakes Tana, Awassa, Abyata and Shala (McKee, 2007). Unsustainable forms of agriculture are a major cause of environmental degradation (Ambelu et al., 2010), and seasonal incursions by pastoralists with their livestock are exacerbating the situation (Kloos et al., 2010).

2.2 Water Quality

Water quality responds to environmental conditions hence they are good measures and indicators of their ecological characters (Meyer et al., 2008). The quality and condition of an ecosystem including wetlands is a function of either or both natural and anthropogenic influences. For example human influences such as water abstraction for domestic use, agriculture, mining, power generation and industrial production can lead to deterioration in water quality and quantity that not only impact the aquatic ecosystem but also the availability of safe water for human consumption (Waterwatch Victoria, 2009).The conversion of wetlands to agricultural land has had a significant negative impact on water quality and storage in most parts of the world (Brinson & Malvárez, 2002).

According to Safari et al., (2012) on effect of human activities on the degradation and lowering of water quality in Nyaruzinga wetland, collected water samples from six different places (one town supply, one water reservoir) and four contaminated sources near the wetland. The results were compared to both national and WHO guidelines. The different parameters assessed included apparent colour (AC), total suspended solids (TSS), turbidity (Tur), total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH), pH and microbial activity using E. coli as a standard test. Experimental methods were composed of complex metric titration, turbidimetry, pH direct meter reading, spectrophotometry and standard plate count, using membrane filter technique. Results obtained revealed that most of the parameters investigated were not within the range recommended by both national standard and World Health Organization (WHO) guidelines. Such results were mainly attributed to fish farming and sewage discharge from the surrounding institutions.

A study by Twesigye et al., (2011) assessed the impact of land use activities on loss of vegetation cover and water quality in three selected sites within the Lake Victoria Basin using remote sensing technologies and standard water quality analysis techniques. The three study sites were: (i) Nzoia River Basin (Kenya), (ii) Nakivubo Wetland (Uganda) and (iii) Simiyu drainage basin (Tanzania). The physical and chemical analysis of water quality revealed high levels of phosphates and nitrates along the agricultural zones of River Nzoia Basin.

Similarly, Kithiia (2007) examined the changes in water quality that had occurred within the Athi and Nairobi river basins in the last decade focusing on trends in water quality degradation, pollutant sources and pollution levels since the early 1990s to year 2000 and beyond. It drew its major findings from two research projects done within the basins over the same period. The two research projects revealed increasing trends in water quality degradation due to changes in land-use systems. Industrial, population (rural–urban migration) growth and agricultural activities were found to contribute significant amounts of water pollutants, thus degrading the water quality status in the two river basins investigated.

From the previous study on water quality, the focus was mainly on rivers and the status of water as a result of human activities (Twesigye et al., 2011; Kithiia, 2007; Safari et al., 2012). This study will be filling the gap by assessing the water quality in the Ombeyi wetland by conducting the physical and chemical variables such as turbidity, pH and dissolved oxygen. The aim of carrying out such tests was to understand their dynamics as well as recommend the possible measures to be taken to rectify mismanagement by human activities.

2.3 Wetland Vegetation

Wetland vegetations are usually referred to as macrophytes. Macrophytes can either be emergent or submergent. Particularly macrophytes offer cover for fish and substrate for aquatic invertebrates, produce oxygen which assists with overall wetlands processes and functioning in addition to providing food for some fish and other wildlife (Brauman et al., 2007). Macrophytes remove pollutants from overland flow and from groundwater by physically trapping water and sediments, adhering to contaminants, reducing water speed to enhance infiltration, biochemically transforming nutrients and contaminants, absorbing water and nutrients from the root zone, stabilizing soils and eroding banks, and diluting contaminated water (Ludwig et al. 2005).

According to Kattelmann and Embury (1996), the health of Sierra Nevada watersheds depended on the ecological integrity of riparian areas. These lands along water courses influence the entry of water, energy, sediment, nutrients, and pollutants into streams. Fully-functioning riparian areas are critical to aquatic biodiversity and good water quality. The findings indicated that the riparian areas in the Sierra Nevada had been degraded by a long history of placer mining, dam construction, stream flow regulation, overgrazing, logging, road construction, urban development, recreation, and other impacts. Widespread changes in riparian vegetation are believed to have occurred as a result of overgrazing, but their nature and extent have not been quantified. Persistent grazing often prevents the re-establishment of riparian plants that could retard erosion of devegetated stream banks Kattelmann and Embury (1996).

Further study by Baker (2004) performed a change detection analysis for the years 1988 and 2001. The change detection used Landsat-based Tasseled Cap (TC) components and change vector analysis (CVA) to identify locations of wetland/riparian gain or loss in the 13-year period. CVA of TC brightness, greenness, and wetness components reduces the compound errors of multi-date classifications by using a threshold value to separate land cover change from spectral variability between 1988 and 2001 imagery. Only the highly changed pixels were classified using 1988 Landsat imagery and ancillary data. These change pixels were then merged with the 2001 classified image to develop a wetland/riparian map for 1988. The high overall accuracy of the 1988 classification (81%) developed with this procedure showed the benefits of this technique for mapping historical landcover features (Baker, 2004). Comparison of the 1988 and 2001 classifications identified locations where wetlands/riparian areas increased, decreased, or remained stable between these years.

On assessing the impact of land use activities on loss of vegetation cover and water quality in three selected sites within the Lake Victoria Basin, Twesigye et al., (2011) used remote sensing technologies on Nzoia River Basin, Nakivubo Wetland and Simiyu drainage basin. The satellite images revealed that in all the three study sites land vegetation cover has continuously reduced in size. The extent of environmental degradation caused by agricultural, domestic and industrial wastes and how this affects loss of vegetation cover and water quality is discussed.

According to Raburu, (2003) the most common vegetation in Nyando wetland to be Cyperus papyrus, Typha domingensis, Pycreus nitidus, Pennisetum purpureum, Cyperus pectinatus, Phragmites australis, Phragmites, Aeschynomene mimosifolia, Kyllinga bulbosa, Centella asiatica and Sphaeranthus suaveolens. The absence or presence of some particular macrophytes may indicate the level of water quality and general wetland conditions as a result of excessive turbidity, siltation, herbicides, or salinization. On the other hand, overabundance of wetland vegetation may be due to high nutrient levels that likely interfere with lake processes, functions and human activities in a wetland.

From the literature review, previous studies on wetland vegetation assessed by degradation of riparian areas (Kattelmann and Embury, 1996), detection analysis over a period of years (Baker, 2004), remote sensing technologies (Twesigye et al., 2011). Not a single study has assessed the wetland vegetation in Ombeyi wetland in Kenya. This study therefore assessed wetland vegetation in Ombeyi wetland by getting the species composition, diversity, frequency and density using Simpson's index. The Simpson's index reflects dominance because it weighs the most abundant species more heavily than the rare species. It considers the number of species, the total number of individuals and the proportion of the total found in each species. The index expresses the probability that the next species encountered will be a different species. It ranges from 0 to 1, with values near zero corresponding to highly diverse or heterogeneous ecosystems and values near one corresponding to more homogeneous ecosystems (Simpson et al., 1986). A perfectly homogeneous population would have a diversity score of 0. A perfectly heterogeneous population would have a diversity score of 1. This index was used to reflect if there were dominating species.

2.4 Social-Economic Activities

Wetlands provide significant aesthetic, educational, cultural and spiritual benefits, as well as a vast array of opportunities for recreation and tourism. Recreational fishing can generate considerable income: 35-45 million people take part in recreational fishing (inland and salt water) in the United States, spending a total of $24-37 billion each year on their hobby (Millennium Ecosystem Assessment, 2005). Much of the economic value of coral reefs – with net benefits estimated at nearly $30 billion each year – is generated from nature-based tourism, including scuba diving and snorkeling (Balirwa, 2007). Natural vegetation in wetlands and floodplains also provides an important source of off-farm pasture, fodder and forage as dry season grazing for livestock (Wood and Howard-Williams, 2004).

Wetland systems directly support millions of people and provide goods and services to the world outside the wetland. People use the wetland soils for agriculture, they catch wetland fish to eat, cut wetland trees for timber and fuel wood and wetland reeds to make mats and to thatch roofs (Eggert and Lokina, 2008). Direct use may also take the form of recreation, such as bird watching or sailing, or scientific study. Peat soils have preserved ancient remains of people and track ways which are of great interest to archaeologists (Dixon, 2002). Freshwater wetlands have high conservation significance, supporting concentrated populations of birds, mammals, reptiles, amphibians, fish and invertebrate species (Wood & Howard-Williams, 2004). It has been estimated that fresh water wetlands hold more than 40% of the entire world's species and 12% of all animal species (Spellerberg, 2013). Individual wetlands can be extremely important in supporting high numbers of endemic species. In addition to their direct biodiversity significance, wetlands play a vital role in supporting hydrological functions, and therefore underpinning wider freshwater ecosystems (Schuyt, et al. 2004).

Interactions between humans and wetlands are strongly associated with wetland loss and degradation (Muyodi et al, 2010). There also exist traditional/local practices that are compatible with wetland wise use principles that should be documented and promoted (Kansiime, et al, 2007a). Notably human-wetlands interactions are poorly understood. Availability of information on the interactions between wetlands and humans would be useful in mitigating some of these threats, in addition to promoting indigenous knowledge that is beneficial to management and conservation of wetlands (Millennium Ecosystem Assessment, 2005). Research on human use of wetland resources provides good signals on the resource status and to a greater extent the ecological status and health of a wetland (Spellerberg, 2013).

The impacts of main socio-economic activities on Lake Victoria in Musoma Municipality were evaluated by (Musamba et al., 2011). Primary data was gathered by administering the questionnaire to a sample of 220 households. The land use/cover identified were Lake Victoria, CBD, infrastructures, Kitaji swamp, fishing areas, settlement, farms, industrial areas, tarmac road and recreational areas. Findings show that there is a strong relationship (r =91.3%; p=0.001) between the anthropogenic activities and land use type changes. Lack of awareness on the role of wetlands was found to impede the participation of local people to Lake Victoria conservation.

Existing studies have not evaluated the human activities in Ombeyi wetland and their influence on water quality and vegetation. This study assessed the major anthropogenic activities that affect/impact on the wetlands' integrity. The respondents were composed of household heads who filled the questionnaires.

2.5 Legal and Policy Framework on Wetlands in Kenya

Concerning wetland management planning, the global policy context is defined by the processes around the Ramsar Convention and other relevant environmental conservation treaties and conventions, notably the Rio Declaration and Agenda 21, the United Nations Convention to Combat Desertification, and the Convention on Biological Diversity. The regional policy context on the other hand is defined by the integration arrangement between Kenya and its four neighbouring countries within the framework of the East African Community. Currently, there are two important policies relating to the management of wetlands: the Wetlands Conservation and Management Policy 2013 and the Environment Policy 2013. These are important policy discourses that have set the motion towards sustainable wetland management in Kenya. The national context is defined largely by the Constitution, Draft Environment and Wetland Policies 2013, the National Land Policy and legislation introduced to give effect thereto. Also of relevance are other sector specific policies and laws touching on wetland/water resources management.

2.5.1 Land Act, 2012

Under Article 60 of the Constitution, the land policy is mandated to inform the manner in which land is held, used and managed in Kenya, in order to ensure equity, efficiency, productivity and sustainability. The Constitution entrenches the three land tenure systems, namely: public, community and public. Water catchment and specially protected areas are vested in the national government to hold in trust for the people of Kenya. The use and disposition of public land is to be governed by an Act of Parliament. The State shall, inter alia, ensure sustainable exploitation, utilization and management and conservation of the environment and natural resources, and ensure the equitable sharing of accruing benefits; encourage public participation in the management, protection and conservation of the environment; and eliminate processes and activities that are likely to endanger the environment. Community members are required to cooperate with State organs and other persons to protect and conserve the environment and ensure ecologically sustainable development and use of natural resources. The Constitution also introduced the devolved government which will ensure implementation of specific National Government policies on natural resources and environmental conservation, including soil and water conservation and forestry.

2.5.2 National Land Policy

The adoption of the National Land Policy in August 2009 marked the culmination of a long process and was a significant achievement in the search for a lasting solution to the challenge of land governance and management. Although it preceded the Constitution by a whole year, the two processes were closely linked as they both responded to the need for a comprehensive framework for reconciling competing interests over land and natural resources. The National Land Policy highlights the need for policy responses to poor environmental management and inappropriate ecosystem protection and management. It recommends policy responses that include adoption and implementation of Land Use Plans.

It outlines principles to guide the protection of watersheds, lakes, drainage basins and wetlands. These include: prohibition of settlement and agricultural activities in water catchment areas; identification, delineation and gazzettement of all water courses and wetlands in line with international conventions; and integrated resource management based on ecosystem structure regardless of administrative or political boundaries. The Government also commits to ensure that all land use practices conform to land use plans and principles of biodiversity protection, conservation and sustainable development. Ombeyi wetland though cutting across two political boundaries (Muhoroni and Nyando sub counties), it is within the jurisdiction of Kisumu County Government. In spite of the political setting, this comprehensive management plan which adopted ecosystem-based management approaches requiring broader and holistic management regimes across boundaries, provides the necessary overarching frameworks towards managing the wetland resources for posterity.

2.5.3 The Water Act 2016

According to the water act 2002, the major challenges facing the sector are lack of proper inter-linkages as well as poor coordination amongst the various sectors concerned with water and water resources. In its recommendation, an Integrated Water Resources Management (IWRM) approach would ensure coordinated development and management of water, land and related resources in a suitable way. A river basin or catchment is considered the smallest unit of planning and management of water resources. The act seeks to promote social and economic benefits of the people in a catchment area in a manner that is equitable by addressing social, economic and environmental dimensions of water resources management from an ecosystem-wide perspective consideration. The Water Act gives guidelines on use and management of the water resources in the country. Water users are required to obtain a permit for various purposes including for discharge of pollutants into any water resource. The issuance of the permit is subject to public consultation as well as an Environmental Impact Assessment.

In Ombeyi wetland the surrounding community uses the water for purposes such as irrigation, car washing among others. Even though the Act does not define 'wetlands' or make any direct reference to wetlands its definition of "water resource" ("any lake, pond, swamp, marsh, stream, watercourse, estuary, aquifer, artesian basin or other body of flowing or standing water, whether above or below ground") does encompasses wetlands. Further activities such as policy formulation, water resource management, regulation of water and sewerage services provision and financing are mandated to different institutions. The act has also devolved decision-making processes to the regional and local levels, thereby promoting stakeholder participation, including that of communities and the private sector.

2.5.4 Forest Act 2005

This act is supported by the Forests Act of 2005 (No. 7 of 2005) and the Forests (Participation in Sustainable Forest Management) Rules, 2009 Kenya Gazette Supplement No. 754. The act guides on application of authorizations on sustainable use of forests. Sessional Paper No. 1 of 2007 on Forest Policy introduced significant reforms in the management of forest resources including an ecosystems approach to the planning and management of forests and the involvement of forest adjacent communities and other stakeholders in forest management and conservation. Although it does not specifically address wetlands, the Policy and its objectives have a bearing on the management of wetlands resources. The act seeks to promote the participation of the private sector, communities and other stakeholders in forest management to conserve water catchment areas, create employment, reduce poverty and ensure the sustainability of the forest sector.

Wetlands have important implications for water catchment. It expands forest management to embrace preservation of religious and cultural sites, traditional medicinal sources, water catchments, and habitats for endemic and threatened species of flora and fauna, categories that no doubt include wetlands. It empowers the Minister, upon the recommendation of the forest conservation committee for the area within which a forest is situated, the local authority and the Board of the Kenya Forest Service to declare as a local authority forest any land under the jurisdiction of a local authority that is an important catchment area, a source of water springs, or is a fragile environment; or is rich in biodiversity or contains rare, threatened or endangered species". Wetlands conservation and protection can be enhanced through the powers stipulated in the forest act 2005.

2.5.5 Environmental Management and Coordination (Amendment) Act, 2015

EMCA states that every person is entitled to a clean and healthy environment and has the duty to safeguard the same. In order to achieve the goal of a clean Environment for all, new projects listed under the Second Schedule of Section 58 of EMCA No. 5 of 2015 shall undergo an Environmental Impact Assessment. EMCA is a framework law on environment that establishes the institutional framework and makes elaborate provisions for management of the environment and its component parts including wetlands. It establishes the National Environment Management Authority (NEMA) to exercise general supervision and co-ordination over all matters relating to the environment and to be the principal instrument of Government in the implementation of all policies relating to the environment. Among the tools and mechanisms the Act establishes for environmental conservation and management include environmental planning from the local to the national level, environmental impact assessment, environmental audit and monitoring, and environmental restoration and conservation orders. The Act makes elaborate provisions for protection and conservation of wetlands under Sections 42 and 43. It prohibits activities that compromise the integrity of wetlands, requiring prior written approval of the Director General of NEMA, which can only be given after an environmental impact assessment (EIA).

2.6 Theoretical Framework

2.6.1 DPSIR Framework

DPSIR is an acronym that represents five components (Drivers, Pressures, States, Impacts and Responses) assumed as sources of the processes of interest for the description of the ecosystem. The framework was proposed by OECD (OECD, 1999). According to the DPSIR framework there is a chain of connecting links starting with 'driving forces' (economic sectors, human activities) through 'pressures' (emissions, waste) to 'states' (physical, chemical and biological) and 'impacts' on ecosystems, human health and functions, eventually leading to political 'responses' (prioritization, target setting, indicators) (Caponigro and Iannucci, 2010).

Indicators for driving forces describe the social, demographic, and economic developments in societies and the corresponding changes in lifestyles, overall levels of consumption, and production patterns (Caponigro and Iannucci, 2010). The primary driving forces are population growth and developments in the needs and activities of individuals. These primary driving forces provoke changes in the overall levels of production and consumption. Through these changes in production and consumption, the driving forces exert pressure on the environment (Gunderson 2000).

Pressure indicators describe developments in the release of substances (emissions), physical and biological agents, the use of resources, and the use of land. The pressures exerted by society are transported and transformed in a variety of natural processes to manifest in changes in environmental conditions (Corrado Michele and Valter, 2011). Examples of pressure indicators are CO2 emissions per sector; the use of rock, gravel, and sand for construction; and the amount of land used for roads. State indicators provide a description of the quantity and quality of physical phenomena (such as temperature), biological phenomena (such as fish stocks), and chemical phenomena (such as atmospheric CO2 concentrations) in a certain area.

State indicators may, for instance, describe the forest and wildlife resources present, the concentration of phosphorus and sulfur in lakes, or the level of noise in the neighborhood of airports (Corrado et al., 2011). Due to environmental pressure, the state of the environment changes hence impacts the social and economic functions on the environment, such as the provision of adequate conditions for health, resources availability, and biodiversity. Impact indicators are used to describe these impacts. Impacts occur in a certain sequence: air pollution may cause global warming (primary effect), which may, in turn, cause an increase in temperature (secondary effect), which may provoke a rise in sea level (tertiary impact), which could result in the loss of biodiversity.

Response indicators refer to responses by groups (and individuals) in society as well as government attempts to prevent, compensate for, ameliorate, or adapt to changes in the state of the environment (Caponigro and Iannucci, 2010). Some societal responses may be regarded as negative driving forces since they aim to redirect prevailing trends in consumption and production patterns. Other responses aim to raise the efficiency of products and processes through stimulating the development and penetration of clean technologies (Corrado et al., 2011)

The DPSIR framework related to the study topic on assessment of ecology of Ombeyi wetland and livelihood dynamics of the local communities in Nyando Sub-county. The local communities' population (education level and age) and activities such as grazing and farming represented the drivers. The pressures exerted were indicated by the settlement, road construction, over-cultivation and wastes. The state was presented by the availability of natural vegetation and water quality while impact was indicted by changes in pH, turbidity and dissolved oxygen. The responses were the attempts by the local community, non-governmental organizations or the devolved government to reclaim the Ombeyi wetland.

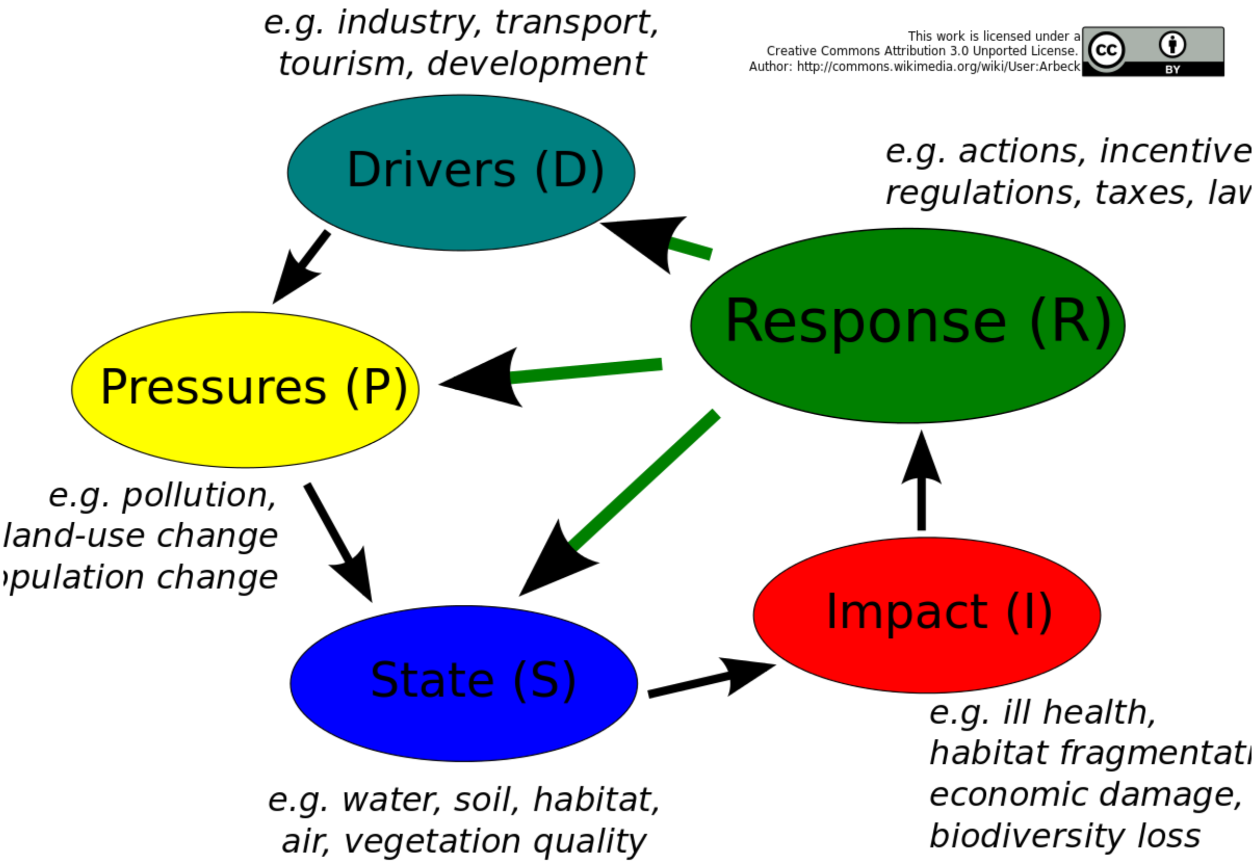


Figure 1: DPSIR Framework; Source: EEA (2003)

2.7 Conceptual Framework

The aim of the study was to examine the ecological assessment of Ombeyi wetland and livelihood dynamic of the adjacent dependent communities. The independent variables with their indicators are quality of water (BOD, COD, pH and turbidity), status of vegetation (vegetation cover, species diversity) and human activities (agriculture and development). The dependent variable was the health status of Ombeyi wetland. The dependent variable is the adaptation techniques while the intervening variables are the policy and legal frameworks and institutional arrangements.

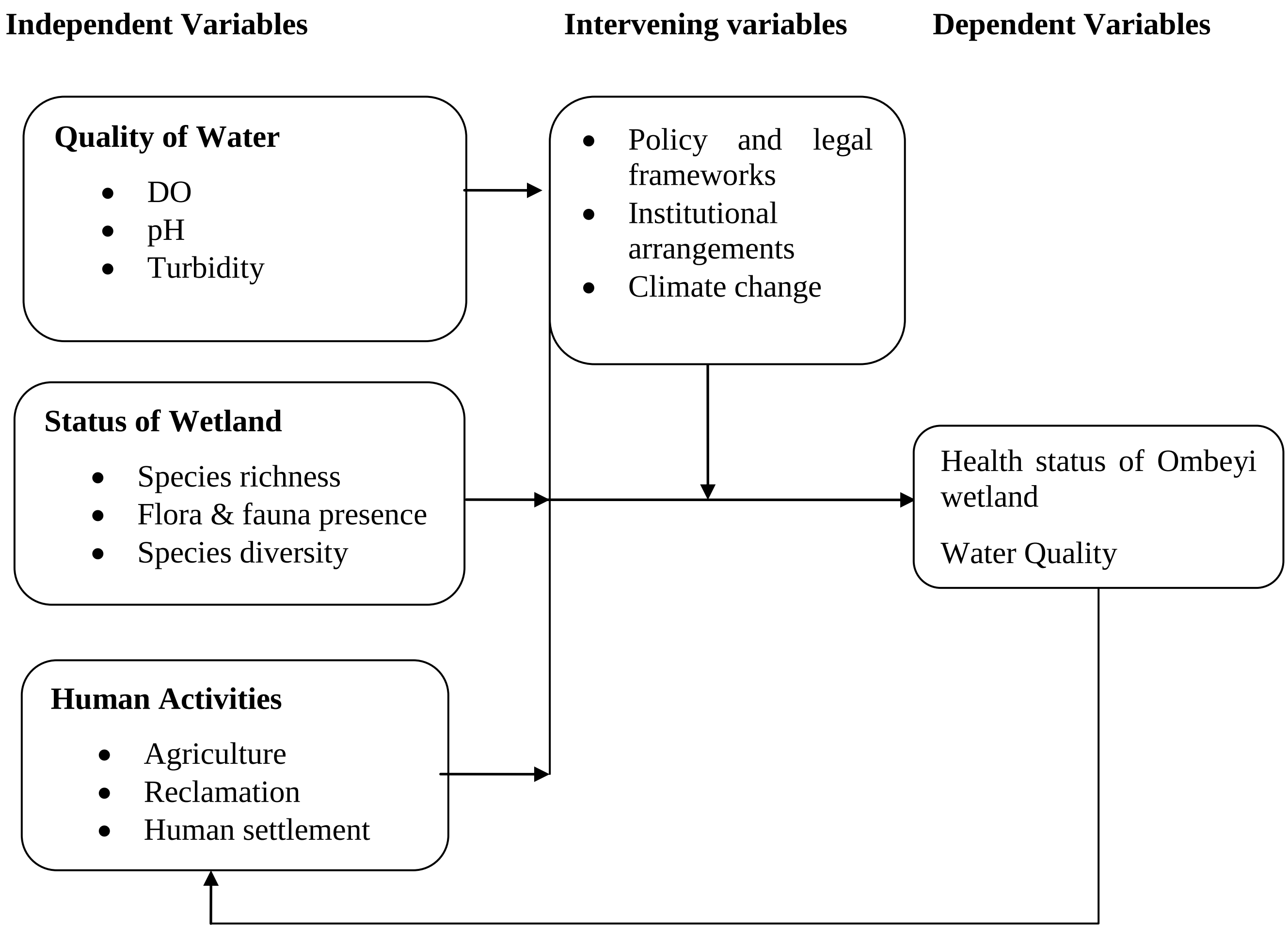


Figure 2: Conceptual Framework for the study

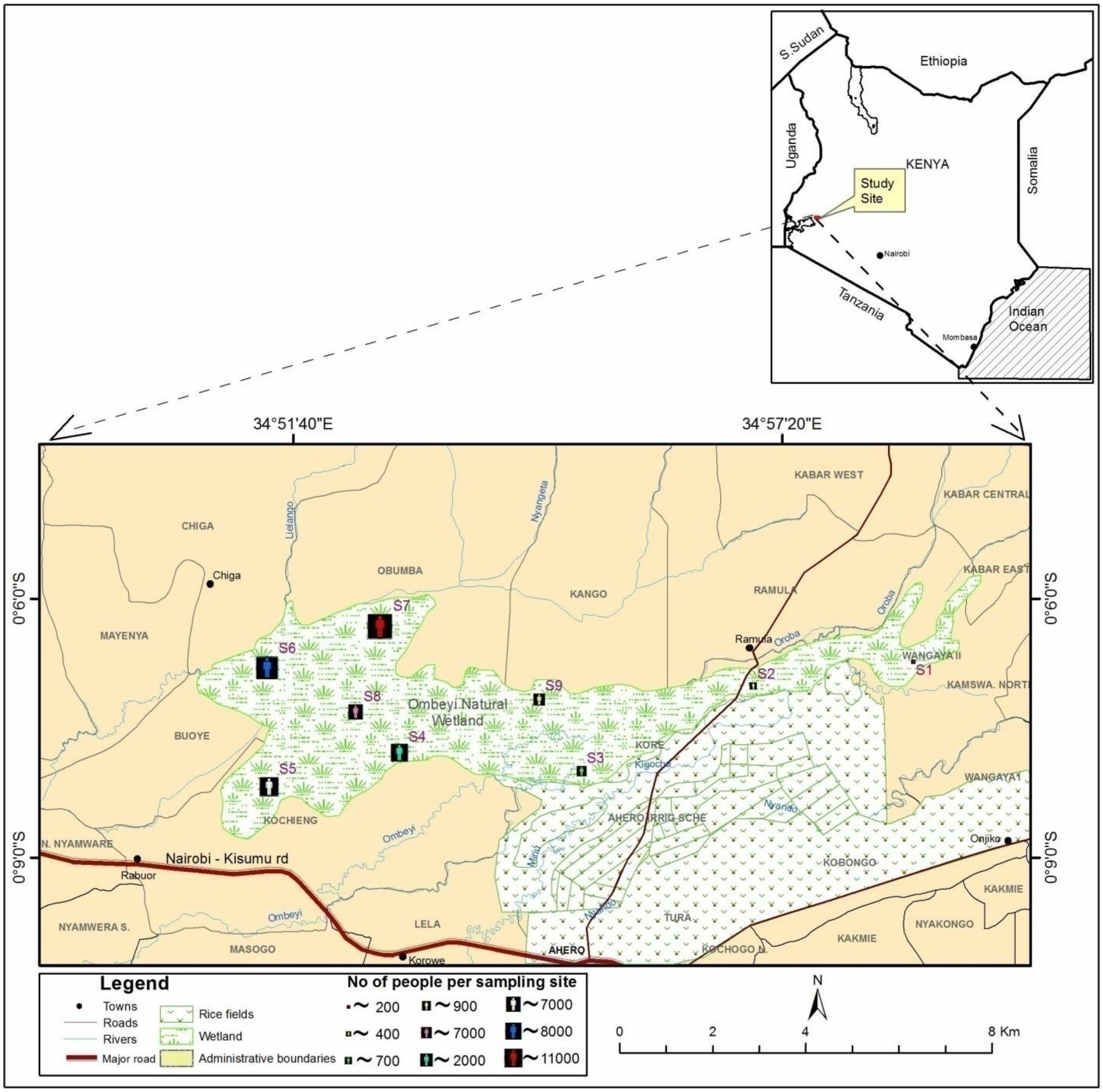
CHAPTER THREE
MATERIALS AND METHODS

3.1 Description of Study Area

This study was conducted in Ombeyi Wetland (0°09'10.3"S 35°04'24.0"E) in Nyando Sub County. The wetland is within the Lake Victoria Lowlands and Kano Floodplains. It is enclosed to the East by Tinderet Hills and to the North by Nandi Escarpment. The wetland cuts across the Nyando and Kisumu East Sub Counties within the Kisumu County and forms a complex ecosystem comprising of several streams, rivers and swamps (Figure 3). Ombeyi wetland occupies an area of approximately 1037ha and is served by river Ombeyi (Muyodi, Bugenyi and Hecky, 2010). The climatic conditions can be classified as semi-humid with an annual rainfall recorded as 1204mm on average and distributed in three rainfall seasons (March - May, August and Nov-December) (LVEMP, 2014).April and May comprise the wettest months accounting for 25% of annual rainfall (UNEP, 2006).

The community adjacent to the wetland comprises the indigenous people whose main language of communication is dhuluo (Koyombo and Jorgensen, 2006). Ombeyi Sub County where the wetland is located has a poverty level of 63% (LVEMP, 2014). Over 70% of the population living around the wetlands live below poverty level (earning less than US$ 1.00 per day) and Nyando sub-county is one of the counties with the highest prevalence in Kenya making them to overexploit and degrade this fragile wetland ecosystem (LVEMP, 2014).

The main economic activities around the wetland include mat-making, fishing and farming. Mat-making is done by both men and women. Most young men between the ages of 18-35 involve themselves in fishing while majority women carry out farming. Cattle’s keeping is another activity that is done within the wetland. Some other livelihood activities around the wetland include bodaboda riding, car wash and sand harvesting (Maithya et al., 2011).



Source: Map Modified from Kisumu County Integrated Development Plan 2013 - 2017

Figure 3: Map of the study area showing sampling sites S1 to S9 corresponding to Wangaya to Kang'o respectively.

3.2 Research Design

An ecological survey study design was adopted in this study. Stratified sampling technique was used in selecting the various sites across the Ombeyi wetland. The sampling sites were selected on the basis of human use and hydrology and accessibility and land-use. Wangaya II village (site 1) was the most accessible as it had roads and human settlement. Site two (Oroba) was mainly used for grazing, site three (Kore) had minimal human activities while site four (Bwanda) consisted of farming and settlement. Site five (Kochieng) and site six (Buoye) were distinguished for they had car washing and motorbikes washing activities. Site 7 (Obumba) and site 8 (Kombura) were mainly used for farming activities while site 9 (Kang'o) was less invaded by human activities. Simple random sampling was used in selecting plot in each of the sites which acted as a representative of the entire site.

3.3 Sampling

3.3.1 Measurement of water physicochemical parameters

Random sampling was used in selecting points in each of the sites where water was drawn into a one litre glass.

3.3.2 Assessment of vegetation structure and composition

Random quadrat method was used to conduct vegetation sampling where measurement of vegetation structural attributes (species composition, density and frequency) was carried out in the nine sites of the study area selected at random. The plot size measured 500m by 50m. Inside each plot, quadrats of size10m by 10m for Shrubs, 4m by 4m for herbs and forbs and 1m by 1m for grasses were placed at random Bonham (2013).

3.3.3 Characterization of socioeconomic factors and livelihoods of the communities

In order to evaluate the livelihood dynamics of the local communities, a stratified random sampling technique was employed to generate the samples. Six villages namely Oroba, Ramula, Kore, Bwanda, Buoye and Obumba were used as the strata. The head of the household was chosen as the respondent and informed consent was obtained from the participants. Participants were educated about the study purpose, the procedures, the risks and benefits, and their consent obtained before involving them in the research. Samples were drawn using systematic random sampling. A total of 90 households were sampled. Sample size was calculated by the formula of proportion allocation according to Kothari, (2004).

3.4 Data Collection

3.4.1 Water physicochemical parameters

Water quality variables sampled were pH, turbidity and dissolved oxygen (DO). Water samples were collected in a 1-litre glass container from each site. The same procedure was followed in the two subsequent months (December and January) and an average was calculated.

pH: Colorimetric method

Apparatus used were BDH Indicator (Universal Indicator) and test tubes. About 10ml of the sample was taken in a wide mouth test tube; 0.2ml of BDH indicator was added and shaken gently. The colour developed was matched with the chart and the pH noted. The colorimetric indicator method was used only for approximate pH values on a scale ranging from 0-14.

Turbidity: Standard Turbidity Suspension

Nephelometric measurement was based on comparison of the intensity of scattered light of the sample with the intensity of light scattered by a standard reference suspension (Formazin polymer) under similar conditions.10ml of the stock solution was diluted to 100ml with distilled water to give a standard solution of 40NTU.

The nephelometer was calibrated using distilled water (Zero NTU) and a standard turbidity suspension of 40NTU. The thoroughly shaken sample was taken in the nephelometric tube and the value is recorded. Turbidity (NTU) = (Nephelometer readings) (Dilution factor) If the turbidity of the sample was more than 40 NTU, then the sample was diluted and the dilution factor was accounted in final calculations.

Dissolved Oxygen: Membrane electrode method

The membrane electrode had a sensing element protected by an oxygen-permeable plastic membrane that served as a diffusion barrier against impurities. Under steady conditions, the electric current read was directly proportional to the D.O concentrations (electric current is directly proportional to the activity of molecular oxygen). Oxygen-sensitive membrane electrode and lab glassware were the apparatus used and calibrations were carried out following the manufacturer's calibration procedure. The electrode was dipped into the sample, and the reading noted.

3.4.2 Vegetation structure and composition

Since the entire study location was covered with grass related vegetation, a plot of 1m by 1m was considered convenient for the study. Percentage vegetation density was determined by dividing the total number of plant species within each quadrat by the area of the quadrat and multiplying the results by100.

- $\% \text{ density} = \frac{\text{species number in a quadrat}}{\text{Quadrat area}} \times 100$

Frequency was calculated by dividing the number of quadrat in which a particular species occurred by the total number of quadrants studied (9) and multiplying the result by 100.

- $\% \text{ frequency} = \frac{\text{No. of quadrats in which a species occur}}{\text{Total of quadrats studied}} \times 100$

Species diversity was calculated using the Simpson index shown below;

$$D = 1 - \left(\frac{\Sigma\, n(n-1)}{N(N-1)} \right)$$

n = the total number of organisms of a particular species

N = the total number of organisms of all species

3.4.3 Socio-Economic factors and livelihoods of the communities

To study the social economic activities of the local communities, focused group discussions were conducted and a questionnaire was developed (Appendix A). A total of ninety questionnaires were administered. The questionnaire addressed the socioeconomic characteristics of the community, benefits of the wetlands, the activities carried out in the wetland and their contribution to deterioration of the wetland as per the water quality and vegetation species.

3.5 Data Analysis

3.5.1 Water physicochemical parameters

Data on physicochemical parameters of water was analyzed using both descriptive and inferential statistics. The inferential statistics included t-test and (ANOVA)

3.5.2 Vegetation structure and composition

Excel spreadsheets were used to display the data in tables and bar graphs.

3.5.3 Socio-Economic factors and livelihoods of the communities

Chi-square was used to analyze socioeconomic factors and an analysis was carried out using Statistical Program for Social Sciences (SPSS) version 20.0.Summary of data analysis is provided in Table 3.1.

Table 3.1: Data Analysis

Study Objective	Variables	Data analysis tool
To examine and compare the quality of water from selected points in Ombeyi wetland	pH Dissolved oxygen (DO) Turbidity	Descriptive statistics ANOVA
To assess the status of wetland vegetation in Ombeyi wetland	Density Frequency Composition	Descriptive statistics
To characterize the socio economic factors and livelihoods of the communities dependent on Ombeyi wetland across selected sites	Occupation Education Age Source of income Income level	Descriptive statistics,

CHAPTER FOUR

RESULTS

4.1 Water quality parameters

The results for sites sampled are presented as in Table 4.1. Water quality variables that were measured included pH, dissolved oxygen (DO) and turbidity (total suspended solids)

Table 4.1: Physico-chemical characteristics measured at sites S1-S9

	Mean ± SE										
Parameter	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**F**	**P**
pH	6.7±0.21	7.5±0.34	6.8±0.12	7.8±0.23	7.3±0.39	7.9±0.46	7.4±0.15	6.9±0.20	7.3±0.09	2.36	0.06
Dissolved $_o$ (mgl^{-1})	6.9±0.27	7.3±0.07	6.8±0.15	6.9±0.42	6.4±0.64	6.2±0.16	7.2±0.12	7.0±0.11	6.3±0.27	1.62	0.19
Turbidity (NTUs)	82.7±1.33	114±3.05	90.3±12.86	87.3±4.37	113.3±5.81	82.7±2.67	129±8.50	86±5.03	124±9.02	7.67	0.00

4.1.1 Water Turbidity

The mean water turbidity varied significantly between sites ($F=7.67$: $DF=8$, $P<0.01$). Post hoc analysis revealed that mean water turbidity was highest at site S7 (129±8.5 NTUs) and lowest at site 1 (82.7±1.33 NTUs) (Figure 4.1).

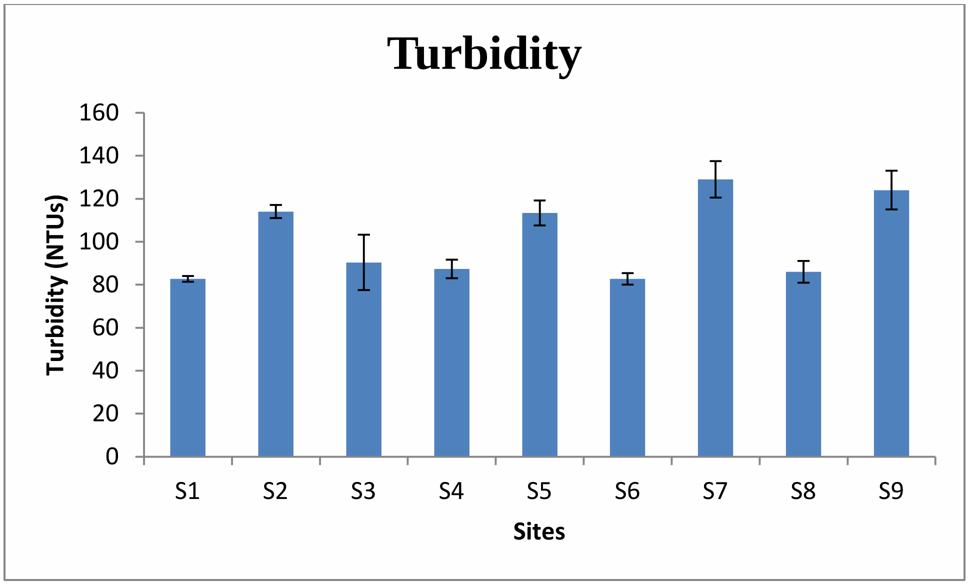


Figure 4.1: Mean water turbidity at the study sites at Ombeyi wetland

4.1.2 Water pH

The mean water pH values were not significantly different amongst the study sites (F=2.36: DF=8, P>0.05). While not significant between sites, the values were within the WHO safe range (6-9) indicating that human activities had low effect on the chemical and biological status of the wetland. Site S6 (Buoye) was high because of its close proximity to the rice field while site one was low because of the river's oxygen matter, which causes oxygen deficiency due to eutrophication.

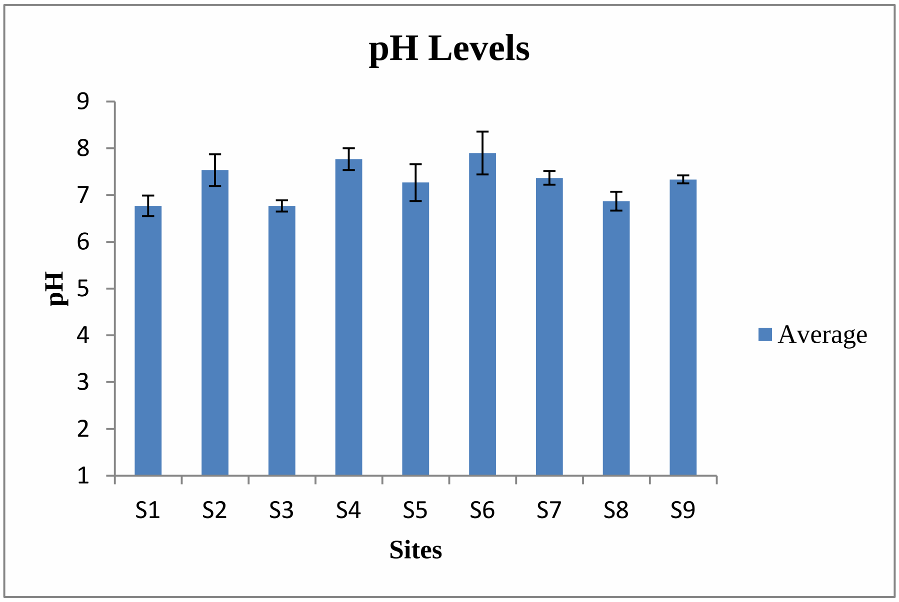


Figure 4.2: Mean Water pH at the study sites at Ombeyi wetland

4.1.3 Dissolved Oxygen (DO)

The mean dissolved oxygen did not differ significantly amongst sites (F=1.62: DF=8, P>0.05) Mean dissolved oxygen was highest at sites S2 (7.3±0.07mgl^{-1}) and lowest at site S6 (6.2±0.16 mgl^{-1}) (Figure 4.3).

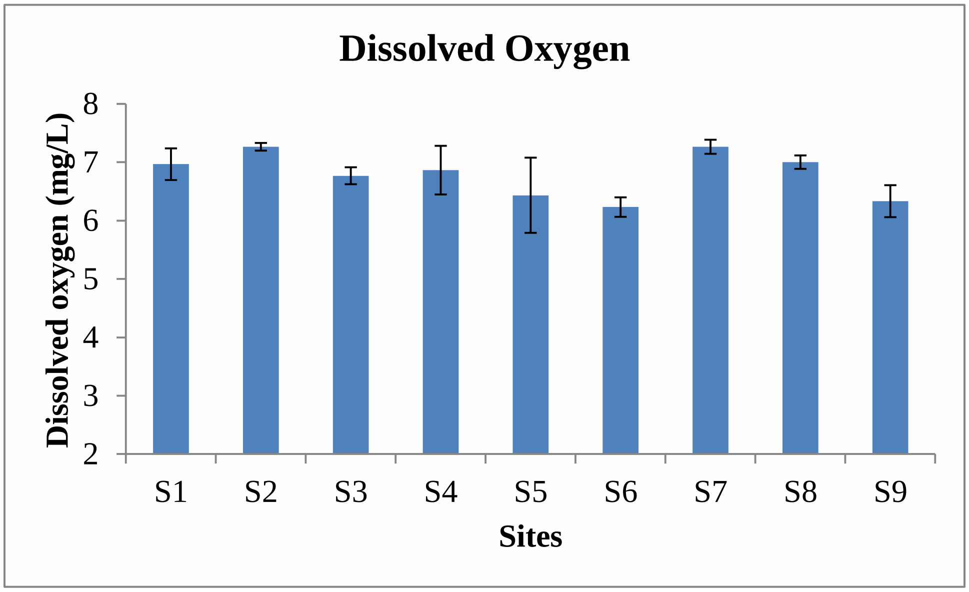


Figure 4.3: Mean dissolved oxygen at the study sites at Ombeyi wetland

4.2 Wetland Vegetation

4.2.1 Species Composition

The proportion of various plant species in the nine sites in relation to the total of the study area were expressed in terms of relative cover. The individual value (percent cover) for the group of fifteen species was divided by the total value of the entire population. Composition allowed the comparison of vegetation communities at various locations within the same ecological sites. A total of 15 species were encountered during the study and their presence (+) or absence (-) is indicated (Table 4.2).

Table 4.2: Species composition of macrophytes at Ombeyi wetland vegetation (+) indicates vegetation presence and (-) indicates absence

			Vegetation presence									
Order	**Family**	**Plant Species**	S1	S2	S3	S4	S5	S6	S7	S8	S9	Total
Apiales	Umberlifers	Centella asiatica	+	+	+	+	+	+	+	+	+	9
Caryophyllales	Aramanthaceae	Amaranthus dubius	+	+	+	+	-	-	+	+	-	6
Commelinales	Commelinacae	Commelina spp	-	+	+	+	+	+	-	-	-	5
Fabales	Fabaceae	Centrosema pubescens	+	+	+	+	-	-	-	+	+	6
	Cyperaceae	Pycreus nitidus	+	+	+	+	+	+	+	+	+	9
		Trifolium vesiculosum	+	+	+	+	+	+	+	+	+	9
Poales	Grasses	Cynodon dactylon	+	+	-	+	+	+	+	+	+	8
		Paspalum scrobiculatum	+	+	+	-	-	-	-	-	-	3
		Pennisetum clandestinum	+	+	+	+	-	+	+	+	+	8
		Pennisetum purpureum	-	+	-	+	+	+	+	+	-	6
	Poaceae	Cynodon plectostachyus	+	+	+	+	-	-	-	-	+	5
	Sedges	Cyperus papyrus	-	-	+	+	+	+	+	-	-	5
		Kyllinga bulbosa	-	+	+	+	-	-	+	+	-	5
	Typhaceae	Typha domingensis	-	-	+	+	+	+	-	+	-	5
Solanales	Night shade	Solanum nigrum	+	+	-	-	+	+	-	-	-	4
Totals			10	13	12	13	9	10	9	10	7	**N 93**

Sites S4 and S2 had the highest number of species with 13 each followed by site S3 with 12 species. C. asiatica, P. nitidus and T. semipilosum appeared in all the sites because they all had high quality forage and were tolerant of heavy grazing. The grass family had the highest number of species including Cynodon dactylon, Paspalum scrobiculatum, Pennisetum clandestinum and Pennisetum purpurium. Paspalum scrobiculatum was only recorded in three sites while Solanum nigrum presence was found in four sites.

Kyllinga bulbosus and most of the Cyperus spp and C. papyrus were used for making mats and baskets as well as thatching houses. They were also harvested for commercial purposes. The most important and threatened wetland plant was Cyperus papyrus which had been seriously disturbed due to increased anthropogenic activities in the area.

4.2.2 Species density and frequency of macrophytes at Ombeyi wetland vegetation

The species densities and relative frequencies were calculated for all the sites. The species with the highest occurrences were Centrosema pubescen, Cyperus papyrus, Pennisetum clandestinum, Centella asiatica, and Cynodon dactylon. The other species such as Amaranthus dubius, Kyllinga bulbosa, Pycreous nitidus and Typha domingiensis had very low densities (Table 4.3)

Table 4.3: **Species density and frequency of macrophytes at Ombeyi wetland vegetation**

Vegetation Species	Plot frequency	Plot density	Frequency (%)	Density (veg/m^2)
Aeschenomene mimosifolia	6	18	66.7	2
Amaranthus dubius	6	19	66.7	2.11
Centella asiatica	5	18	55.6	2
Centrosema pubescen	6	19	66.7	2.11
Commelina spp	4	19	44.4	2.11
Cynodon dactylon	4	17	44.4	1.89
Cynodon plectostachyus	5	20	55.5	2.22
Cyperus papyrus	5	20	55.5	2.22
Pycreus nitidus	8	18	88.7	2
Kyllinga bulbosa	5	18	55.6	2
Solanum nigrum	4	30	44.4	3.33
Trifolium semipilosum	9	19	100	2.11
Pennisetum clandestinum	8	19	88.9	2.11
Paspalum scrobiculatum	4	20	44.4	2.22
Typha domingiensis	3	18	33.3	2
Pennisetum purpureum	6	20	66.7	2.22

Trifolium semipilosum had the highest frequency (9) followed by Pycreus nitidus and Pennisetum clandestinum (8) each. Other most encountered plant species were Amaranthus dubius, Pennisetum purpureum, Centrosema pubescens and Aeschenomene mimosifolia (6). Wetland vegetation such as Cyperus papyrus was observed to have been exploited in many areas within the wetland.

4.3 Socio-Economic Factors Impacting the Wetland

The socio-economic factors are an important aspect in helping identify the engagement of the surrounding communities and how their livelihood affects the Ombeyi wetland. It plays a major role in helping understand the susceptibility of the food security in the community. The study looked at the respondents' daily activities, common activities and conservation measures that were taking place within the wetland.

4.3.1 Characterizing the respondents

Ninety questionnaires were issued from which 73 (81%) were returned. There were more female respondents (75%) than male respondents (25%). 36% of the respondents were within age category 30-39 years, 31.5% of age 20-29 years, 16.4% of age less than 20 years while the remaining 12.3% and 4.1% were of age 40-49 years and 50-59 years respectively. A higher number of the respondents had secondary level of education (40%) followed by primary level (35%). Few respondents had tertiary level education (15%) and no formal education was (10%).

55% of the respondents stated that they engaged in cultivation and farming (planted arrow roots, maize and beans) as a full time job, 20%were involved in fisheries and 15% kept livestock (cattle, goats, sheep and donkeys. 10% were involved in various informal businesses (welders, bodaboda operators, etc).

4.3.2 Effects of the activities practiced around the wetland and their impacts on the Ombeyi wetland

The respondents were asked to indicate the extent of the effects of their daily activities practiced around the wetland and their impacts on the wetland using a scale of 1-5 where 1= no extent 2=little extent 3=moderate extent 4=great extent 5= very great extent.

Table 4.4: Respondents perception on the effects of the activities practiced around the wetland and their impacts on the Ombeyi wetland using a scale of 1-5 where 1= no extent 2=little extent 3=moderate extent 4=great extent 5= very great extent.

Effects of human activity	**Perception**				
	No extent	Little extent	Moderate extent	Great extent	Very great extent
Water pollution	5.5	11	13.7	57.5	12.3
Loss in plant species	5.5	8.2	20.5	54.8	15.1
Invasive species emergence	2.8	15.1	27.4	47.9	9.6
Loss of animal species	5.5	1.4	30.1	56.2	8.2
Flooding	2.8	9.6	47.9	15.1	27.4

The study sought to find out the effects that the activities practiced around the wetland had on the wetland/environment. The respondents indicated that activities around the wetland to a great extent caused water pollution, loss of plant species and loss of animal species They further indicated that the activities to a moderate extent contributed towards flooding and emergence of new invasive plant species.

4.3.3 Coping strategies employed by local the community to dwindling wetland resources

The respondents identified unsustainable consumption of wetland resources to the decreasing services offered by the wetland. They were therefore asked what they were doing in order to protect the wetland and were to respond on a scale of 1-5 where 1=strongly disagree 2=disagree 3=undecided 4=agree 5=strongly agree. Table 4.5 summarizes their responses.

Table 4.5: Respondents perception to the protection measures needed to conserve Ombeyi wetland on a scale of 1-5 where 1=strongly disagree 2=disagree 3=undecided 4=agree 5=strongly agree.

Effects	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
Stop waste disposal on the wetland	0	0	13.2	80.4	6.4
Stop building too close to the wetland	15.1	11.5	10.5	54.8	8.7
Stop all economic activities on the wetland	2.8	15.1	27.4	47.9	9.6
Involving the authorities	5.5	30.1	1.4	56.2	8.2

The respondents agreed that to protect the wetland, building too close to the wetland and waste disposal on the wetland was to be stopped. They were undecided whether voicing their concerns to the authorities could protect the Ombeyi wetland. Stopping all economic activities on the wetland was not indicated as a way of protecting the wetland.

4.3.4 Local community perception on factors affecting implementation of wetland policies

The respondents were further required to indicate their level of agreement on the factors affecting the implementation of wetland policies and management plan in the order of 1=strongly disagree 2=disagree 3=undecided 4=agree 5=strongly agree. Table 4.6 summarizes their responses.

Table 4.6: Local perception on factors affecting the implementation of wetland policies and management plan in Ombeyi wetland

Activity/action	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
Political influence	5.5	11	13.7	57.5	12.3
Change in government	5.5	8.2	20.5	54.8	15.1
Corruption	2.8	15.1	27.4	47.9	9.6
Poverty levels	5.5	1.4	30.1	56.2	8.2
Cost of demolition of settlements	0	16.4	16.4	57.5	9.6
Cultural values	2.8	9.6	47.9	15.1	27.4

The respondents agreed that the factors affecting the implementation of wetland policies and management plan were political influence, cost of demolition of settlements and poverty levels.

CHAPTER FIVE:

DISCUSSION

5.1 Water Quality

The mean water turbidity was lowest at S1 and high at S7. These turbidities were higher than the recommended standards by the World Health Organization of not more than 5NTU, and should ideally be below 1NTU for freshwater systems (Orwa et al., 2012). During high flows, water velocities are faster and water volumes are higher, easily stirring up and suspending material from the stream bed, causing higher turbidities. This could be as a result of trampling of grazing animals and the increase in suspended sediment from hinterlands since the study was conducted in the wet season. According to (Palamuleni et al., 2001) turbidities are mainly high during rainy seasons as soil erosion is prevalent. Clearance of the riparian vegetation within the wetland was another possible cause for the high levels of turbidities (Corrado et al., 2011).

There were variations in water pH among sampling sites with the highest average water pH recorded at S6 while the lowest average at S1. The low water pH levels at S1 were possibly caused by deposition of chemical elements in the wetland that had acidic qualities resulting in a decline of the water pH. The pH levels had however not yet reached the toxic levels. WHO, (2004) recommends for clean drinking water to be between the pH levels of 6.5 to 9.5. Kinyua and Pacini (1991) assert that the level of pH can have a direct effect on the physiology of the aquatic organisms.

Dissolved oxygen levels were high at site S2 and low at site S6. High DO at site 2 might be due to low discharge and frequent release of water from the surrounding rice field increasing churning frequencies. According to Verhoeven and Setter (2009) high DO is an indication of healthy wetland conditions. Stagnant water in swamps contains little dissolved oxygen as bacterial activities on organic matter during decomposition consume a lot of it (Blanca and Mitsch, 2012). The low DO at S6 might be as a result of higher processes of decomposition of organic matter. Low DO may be a good indicator of eutrophication due to large nutrient inputs leading to high primary productivity hence organic matter production (Corrado et al., 2011). According to Ebbert (2003), dissolved oxygen is dependent on temperature, pressure and ion concentration. The findings show an overall decline in water quality at Ombeyi wetland.

Agricultural activities and increased human population could have played a significant role in the decline of the water quality.

5.2 Wetland Vegetation

Ground cover was used to determine the watershed stability of the sites in ombeyi wetland, but comparisons between sites were difficult to interpret because of the different potentials associated with each site. Overlapping canopy cover created more problems particularly in mixed communities. For species composition to be determined, the canopy of each species was counted regardless of any overlap with other species. Because watershed characteristics were the objective, only the uppermost canopy was generally counted.

A total of 15 species were sampled during the study with site S4 and S2 recording the highest number of species with 13 each followed by site S3 with 12 species. Centella asiatica, Pycreous nitidus and Trifolium semipilosum appeared in all the sites. The grass family had the highest number of species including Cynodon dactylon, Paspalum scrobiculatum, Pennisetum clandestinum and Pennisetum purpurium. Paspalum scrobiculatum were only recorded in three sites while Solanum nigrum presence was found in four sites. This was as a result of deforestation activities and human-induced perturbations within the wetland itself and in the catchment of river Oroba draining into the wetland (Raburu et al. 2012). Raburu, (2003) found the most common vegetation in Nyando wetland to be Cyperus papyrus, Typha domingensis, Pycreous nitidus, Pennisetum purpurium, Cyperus pectinatus, Phragmites australis, Phragmites phragmatoides, Aechenomene mimosifolia, Kyllinga bulbosa, Centella asiatica and Sphaeranthus suaveolens. This however differed with (Rolon et al., 2008) study in southern Brazilian wetlands which found out that among the species typical from permanent wetlands are some euhydrophytes (e.g., Azolla filiculoides, Hydrocotyle ranunculoides, Myriophyllum aquaticum, Hydrocotyle ranunculoides and Utricularia foliosa).

The species with the highest densities were Centrocema pubescen, Cyperus papyrus, Pennisetum clandestinum, Centella asiatica, and Cynodon dactylon. The other species such as Amaranthus dubius, Kyllinga bulbosa, Pycreous nitidus and Typha domingensis had very low densities. Trifolium semipilosum had the highest frequency followed by Cyperus rotundus. Other most encountered plant species were Pycreous nitidus, Centella asiatica and Cynodon dactylon. According to (Rolon et al., 2008), the differences in the richness of aquatic macrophytes at the wetlands may result from the environmental heterogeneity in the landscape scale (e.g. altitude variations, size of the ecosystems, hydro period, connectivity and environmental matrix) or in micro-scales (e.g. habitat diversity and physic-chemical conditions of the water and sediment).

Changes to vegetative and reproductive output have the potential to alter species population dynamics and potentially change the vegetation community. Rolon et al., (2008) indicated that the structural characteristics of the ecosystem (area and diversity of habitat) and the water chemical conditions influenced independently the composition of the aquatic macrophytes, presenting additive effects on the macrophytes composition. At Ombeyi wetland the changes were brought about by cultivation for agriculture and grazing thus leading to over consumption of the species.

5.3 Social Economic Factors

The most common activity was farming followed by fishing and cattle grazing. Demographic changes due to increased commercialization of wetland resources such as papyrus and fish, and the demand for food and grazing land during the dry season has seen an influx of people into the Ombeyi wetland (Maithya et al., 2011). Other activities in the area were artisan (welding, carpentry, and electronics), trading, bodaboda jobs, sand harvesting, brick making and mat making. Osumba et al. (2010) found out that other than harvesting papyrus, fishing, livestock rearing and subsistence farming were common alternative livelihood strategies.

According to (Kiwango et al., 2013) land use in wetland basins result in reduction of water quality through increased turbidity, reduction in water volume due to evaporation, high temperatures, and varying pH levels thus reducing suitability of the wetland water.

Ombeyi wetland has continued to change as a result of natural and human pressures like changes in rainfall patterns and the demand for land for growing crops (Birdlife International, 2004; Owino and Ryan, 2007). According to the residents, changes in the ecosystem became more pronounced in the 1980s when the community intensified farming, livestock herding and papyrus harvesting. In the past, people depended more on fishing as a source of food and income. However, the community lost income from fisheries due to deterioration of water quality and the spread of water hyacinth in the lake (Juma, 1989; GoK, 2000).

CHAPTER SIX:

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The findings of this study showed that there were variations in the mean values of various water quality parameters measured throughout the sites. Factors such as farming and cultivation among others played a role in influencing the water quality at Ombeyi wetland.

Vegetation at sites S9, S8, S7 and S6 showed better wetland vegetation as evidenced by high species richness, composition and diversity of macrophytes. The wetland vegetation was however poorer at sites S1, S2, S3 and S4 as indicated by low species richness, composition and diversity of macrophytes. The papyrus reeds for example that are used for mat making and thatching have been consumed at a very high rate. This was as a result of an increase in anthropogenic activities such as grazing, over-cultivation and motorbike washing which were common in many points across the wetland. The implication is loss of land productivity, deteriorating ecosystem health and loss of community livelihoods.

The community at Ombeyi wetlands relied mainly on fishing, farming and grazing as their source of income. The other commercial activities around the wetland such as bodaboda, sand harvesting, mat making and brick making contributed towards deterioration of the wetland in one way or another. It is also clear that wetland vegetation which should be dominant within the wetland for its purification have been harvested at a very high rate and replaced with other crops.

6.2 Recommendations of the study

To protect and conserve the diversity, the ecosystem services provided by the wetland and indigenous knowledge on local usage of wetland resources in Ombeyi, there is need to manage and conduct human activities in a way that it enhances the resilience of the wetland and its indigenous knowledge on local uses. This study recommends:

i. Encourage enhanced protection and conservation of Ombeyi wetland ecosystem to prevent ground water contamination by nutrients which take place in the inhabited sections of the wetland as a result of human and animal wastes. This can be achieved through development of proper farming systems to curb run-offs and soil erosion which reduces water quality in the wetland.

ii. For enumeration and quantification of plant biodiversity, further in-depth studies on flora and fauna need to be conducted in the region. Considering the potential impact of development on biodiversity, this need to be assessed from a biodiversity viewpoint to indicate the extent to which the disturbance will have impact on biodiversity. Therefore, it is important to apply conservation measures as well as planning management programs for protected and unprotected areas. Moreover, it is necessary to continue with studies in other regions of Ombeyi to identify additional high priority areas of species richness for conservation.

iii. There is need to sensitize the local community members in order to develop alternative means of livelihoods in Ombeyi. This will contribute towards the sustainable utilization of the wetland products. This can be achieved through improvement of policy implementation and awareness creation on the need to protect the wetland through sustainable exploitation of wetland vegetation and natural resources. The relevant authorities in conjunction with the locals should conduct conservation education in order to create awareness on the need to conserve the wetland.

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APPENDICES

Appendix A: Questionnaire for Locals

I am Veryl Obodi, a Master's Science student at the Department of Natural Resources, Egerton University conducting a study on ecological assessment of Ombeyi wetland and livelihood dynamic of the local communities. I request that you participate in the study by providing answers to questions in this questionnaire to the best of your knowledge. The information revealed by the respondents will be treated with a high degree of confidentiality. The respondents are also assured that this information is meant for academic purposes only.

Name of Respondent (optional)………………….. Sub-location: …………………

Part I: General Information

Please fill in the information by ticking appropriately

1) Respondent's gender

   Male [ ] Female [ ]

2) Age group (years)

   Less than 20 [ ] 20-29 [ ]

   30-39 [ ] 40-49 [ ]

   50-59 [ ] Over 60 [ ]

3) Level of Education

   No formal education [ ] Primary level [ ]

   Secondary level [ ] Tertiary level [ ]

Section A: Social Economic Factors

4) What daily activities are practiced in the wetland? Please rank the following options according to the criterion below: 1= no contribution/nothing 2=little contribution 3=moderate contribution 4=high contribution 5= very high contribution.

Job description	1	2	3	4	5
Farming					
Grazing cattle					
Fishing					
Formal sector job					
Trading					
Artisan (welding, carpentry, electronics etc.)					

5) What are the major land use activities around the wetland? Please rank the following options according to the criterion below: 1=not common 2=least common 3=moderately common 4=highly common 5= most highly common.

Activity	1	2	3	4	5
Agriculture (crops and animals)					
Car washing					
Fishing					
Waste disposal					
Carpentry					
Building construction					
Tourism					
Settlement					

6) What have been the effects of the activities above on the environment/wetland? Please rank the following options according the criterion below: 1= no extent 2=little extent 3=moderate extent 4=great extent 5= very great extent.

Effects	1	2	3	4	5
Water pollution					
Loss in Plant species					
Loss in Animal species					
Emergence of invasive species					
Flooding					

Section B: Coping Techniques

7) What do you think can be done to protect this wetland? State your level of agreement on each statement; where 1=strongly disagree 2=disagree 3=undecided 4=agree 5=strongly agree

Coping Techniques	**1**	**2**	**3**	**4**	**5**
Stop waste disposal on the wetland					
Stop building too close to the wetland					
Stop all economic activities on the wetland					
Complain to authorities					
Others					

8) What factors affect the implementation of wetland policies and management plan? State your level of agreement on each statement; where 1=strongly disagree 2=disagree 3=undecided 4=agree 5=strongly agree

Factors	**1**	**2**	**3**	**4**	**5**
Political influence					
Change in government					
Corruption					
Poverty levels					
Cultural practices					
Others					

9) In your own opinion, what needs to be done to avoid further degradation of the wetland?
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

Appendix B: Water Quality data sheet

Date	GPS (start): E/W		N/S
Transect Length	GPS (End): E/W		N/S
Transect Name/No:			
Time start:			Time End:
Weather: **a) Wind:** very windy/moderate/calm		**b)Temperature:**	Hot/Mild/cold
c)Clouds:<25%/25-50%/>50%		**d)Rain:**	None/Light/Heavy

Observers:

Census station	Distance (m)	pH	Dissolved oxygen
1	0		
2	250		
3	500		
4	750		
5	1000		
6	1250		
7	1500		
8	1750		
9	2000		

ADDITIONAL NOTES/REMARKS

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Appendix C: Wetland Vegetation Form

Seasons	Transect	Station readings									Average reading
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Wet	Landward										
	Lakeward										
Dry	Landward										
	Lakeward										
Wet	Landward										
	Lakeward										
Dry	Landward										
	Lakeward										
Wet	Landward										
	Lakeward										
Dry	Landward										
	Lakeward										

ADDITIONAL NOTES/REMARKS

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