EVALUATION OF THE EFFECT OF WETLAND CONVERSION ON QUANTITATIVE SOIL PROPERTIES AND WATER QUALITY IN NAMUTUMBA DISTRICT, UGANDA

BY

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DECLARATION

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

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DEDICATION

This piece of work from my ideas, thoughts and endeavors is dedicated to my beloved parents: My father Ndyanimanya Jackson, my mother Ndyanimanya Dinah and my daughter Nyonyozi Milan Blessing who played a vital role in educating, inspiring and encouraging me to aim higher in widening my academic horizons.

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LIST OF ACRONYMS

UBOS: Uganda Bureau of Statistics

MWE: Ministry of Water and Environment

NEMA: National Environment Management Authority

LUTs: Land Use Types

HFOC: Heavy Fraction Organic Carbon

LFOC: Low Fraction Organic Carbon

GPS: Global Positioning System

GIS: Geographic Information System

TM: Thematic maps

USGS: United States geological survey

Definition of terms

Decomposition: Decomposition is the process by which dead organic matter is broken down into simple organic or inorganic matter.

Mitigation: Mitigation means intervention to limit the detrimental impact of any activity

Risk: Risk is a likely hood of a danger occurring or threatening to occur.

Wetlands: Wetlands are areas covered by water throughout the year.

Hazard: Hazard is a phenomenon or human activity that causes the loss of life or injury or damage.

Subsistence farming: Subsistence farming is a type of farming where production is meant to provide the basic needs of the farmer and his family, with little surplus for sale.

Wetland degradation: Wetlands degradation is the process by which wetland system has degenerated and lost due to effect of natural and human activities.

Water Quality: Water quality is defined as chemical, physical, and biological properties of water.

Land use: Land use refers to the way people utilize land for economic and cultural activities.

ABSTRACT

There are many land use changes happening in Uganda whose impacts have not yet been well studied. This study determined the land use changes that occurred in Namutumba districts between 1988 and 2018 and determined the effect of wetland conversion on soil properties and water quality. Landsat images of resolution of 30 m were downloaded from landsat.org for a period of 30 years; 1988, 1998, 2008 and 2018. Image classification was done using Maximum Likelihood Classification and percentage change in areas under different land uses were determined for years; 1988-1998, 1998-2008 and 2008-2018. Representative soil samples and water samples were collected from cultivated wetlands and uncultivated wetlands in the different water systems of Naiyede, Mpologoma, Naigomba and Namakoko in Namutumba district. The soil and water samples were assessed for pH, organic matter (OM), nitrogen (N), phosphorous (P), potassium (K), boron (B), calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), iron (Fe), sodium (Na), manganese (Mn), cadmium (Cd), lead (Pb), colour, total hardness (TH), total dissolved solids (TDS), total suspended solid (TSS), turbidity, nitrates (NO_3^-), total solids (TS), pH, alkalinity, conductivity (Co), chromium (Cr), phosphates (PO_4^{3-}), chloride (Cl), Cd and sulphates (SO_4^{2-}). Results of land use change indicated a reduction in areas under open water, wetlands, woodland and bush lands and increase in built up areas and wetlands. Cultivation of wetlands significantly ($p<0.05$) increased the amounts of P, Na and Cd. However, there were significantly ($p<0.05$) lower average amounts of quantitative soil properties; pH, OM, N and Cu in cultivated wetlands as compared to the uncultivated. Cultivation of wetlands significantly ($p<0,05$) increased water quality parameters; TDS, TSS, conductivity, Na, Ca, Cl, SO_4^{2-}, PO_4^{3-} and TH. On the other hand, water quality parameters; pH, Co, alkalinity, Mg, Cr, Fe, Cd and $NO3^-$ were not significantly ($p>0.05$) affected by cultivation. It can be concluded that most of the fragile ecosystems in Namutumba District is being converted into built up areas and farmlands and it is negatively affecting some of the soil and water quality parameters. These results are crucial in informing policy makers in designing by-laws and policies for protecting fragile ecosystems such as wetlands from degradation.

CHAPTER ONE

INTRODUCTION

1.0 Introduction

This chapter summarizes the background of the study, statement of the problem, the purpose of the study and the objectives; main and specific objectives. It further presents the hypothesis, significance, scope and the time the study took.

1.1 Background to the study

Wetlands play an important role in regulating climate, filtering of contaminants, sink for carbon storage and a source of food that supports the livelihood of many people in the Sub-Sharan Africa (Wagner et al., 2020; Wood et al. 2013a and Millennium Ecosystem Assessment, 2005). Despite these roles, wetlands in Uganda and the world at large continue to experience great changes while being transformed to other land uses. Available research shows that wetlands are mainly located in places that are occupied by humans, especially agricultural and urban regions (Morardet et al. 2013). Research has also shown negative effects on wetland species and ecosystem function can be expected in such areas due to human activities (McCartney et al., 2010, McCartney et al., 2005 and Molden, 2007). The main causes of wetland loss are drainage and other forms of disturbances associated with agriculture. Approximately 160000 Sq.km of wetland globally has been drained for subsistence farming (Williams, 1991).

Subsistence farming is a type of farming in which most of the farm produce is consumed by the farmer and his family leaving little or nothing to be sold (Mbatha et al., 2021). Its products are meant to provide for the basic needs of the farmer with little left for marketing or sell. Subsistence farming forms two types; primitive and intensive. The former involves shifting cultivation, slashing and burning vegetation farming and pastoral farming on marginal areas while the latter is practiced in fertile land especially in areas where there is lack of enough land thus forcing farmers to maximize food production on relatively small fields (Weceke and Kimenju, 2007). Uganda is faced with intensive subsistence farming in most areas due to the high population density and widespread poverty levels. This puts the country at a risk of land degradation and deforestation with its associated effects of climate change especially among densely populated rural districts like Kabale and Namutumba (Dietrich, 2009).

Uganda is a landlocked country in East Africa and protection of the environment has been one of the key goals of the government of Uganda. Over the past years, great changes have occurred concerning the state of wetlands in Uganda. Recent estimates indicate that more than 7 percent of original wetlands in Uganda have been converted to other land uses with ultimate loss of biodiversity (UBOS, 1999). Wetlands play important roles among them of which include waste recycling, flood prevention, serve as birth sites for fish species, habitat for wildlife, maintain grounds for water supply and improve water quality.

Across Sub-Saharan Africa, 75 percent of the population depended on subsistence farming in the last century (Vanlauwe et al., 2014). Livelihoods are changing and urbanization is increasing (United Nations Human Settlements Programme, 2014), and in the near terms; soils in Sub Saharan Africa must now support a largely subsistence population. Recent research in East Africa on anthropogenic impact on wetlands indicate subsistence farming as a major cause of wetland degradation (Githaiga, 2003). Some of the factors that contribute to wetland degradation in Uganda include population growth, economic modifications, the aspiration for increase in per capita income and other pressures of development undertakings (Mafabi, 2000). Moreover, some studies indicate that large scale agricultural use of wetlands for food production is not sustainable especially where farmers continue to practice subsistence farming especially in Sub Saharan Africa (Waters, 2007). These farmers don't in most cases practice land use and water management systems that are ideal for ensuring sustainability in the functions of the wetland system (Verhoeven, 2010).

Wetland soils may be drained to grow crops at such subsistence levels but production will be short term as the highly organic soils are quickly oxidized and nutrients exhausted (Crisman *et al.*; 1996). These activities which at first seemed to be sustainable will no longer be supported by such wetland soils. Sustainability of agriculture in wetlands that are located in regions of increasing food insecurity and fast-growing population is very important in ensuring their survival. Due to insufficient environmental monitoring, quantitative analysis of the impact of agriculture on wetlands is still limited (Beopolous, 1996).

Environmental information is vital in the planning and decision-making process in efforts to reduce or reverse the impacts that have occurred. However, there is scanty information on effect of wetland conversion on soil properties and water quality in Uganda. The few studies on land use change focused on change of forest ecosystems into other land uses and effects on major soil properties (Mwanjalolo *et al*., 2018; Abonyo et al., 2007; NEMA, 2005 and Wasige et al., 2013). Therefore, this study determined the trend in wetland conversion and determined the effect of these conversions on a broad range of quantitative soil properties and water quality parameters including heavy metals in Namutumba District in Uganda.

1.2 Statement of the Problem

In Uganda, there many unplanned land use changes taking place whose impacts on the environment has not been fully understood. Most notably, the conversion of wetlands into other land uses such as farmland and build up areas in many parts of Uganda. Currently there are many debates about the conversion of wetlands into other land uses due to its impacts on the environment for example flash floods due to siltation of the water ways, loss of wetlands itself and its contribution to climate change due to emissions of carbondioxide (CO_2) and nitrous oxide (N_2O) and deterioration of soil and water quality. Recently, wetlands in Namutumba District have come under the attention of the environmental protection bodies in Uganda because of the high rate wetland conversion. However, the extent of this wetland conversion and associated effects on the environment is not well understood. This study tracked changes in land uses that occurred in Namutumba Districts between 1988 and 2018 and determined the effects of wetland conversion on selected soil properties and water quality parameters. The findings of this research will contribute towards informing any changes to the existing land uses with purposes of promoting soil and water quality.

1.3 Objectives

1.3.1 General objective

The main objective was to evaluate the effect of wetland conversion to other land uses on selected quantitative soil properties and water quality for sustainable management of wetlands in Uganda.

1.3.2 Specific objectives

The specific objectives of the study were:

i. To determine land use changes that occurred in Namutumba District between years; 1988 and 2018,

ii. To determine the effect of cultivation of wetland on selected quantitative soil properties; soil pH, soil organic matter, nitrogen, phosphorous, potassium, calcium, magnesium, copper, zinc, boron, iron, manganese, cadmium, and lead,

iii. To determine the effect of cultivation of wetland on selected water quality parameters; total hardness, total solids, total suspended solids, total dissolved solids, pH, turbidity, alkalinity, conductivity, lead, magnesium, sodium, calcium, chromium, iron, phosphates, chloride, cadmium, and sulphates.

1.4 Hypotheses

The following hypotheses were tested to achieve the above specific objectives:

i. There is a significant reduction in areas covered by fragile ecosystems such as forests and wetlands in Namutumba District because of increase in population,

ii. There is a significant difference in quantitative soil properties between cultivated and uncultivated wetlands due to disturbance of soil structure and application of chemicals,

iii. Cultivation of wetlands significantly reduces the quality of water as compared to uncultivated wetlands because of disturbance of soil structure and use of chemicals.

1.5 Justification

Wetlands are sources of livelihoods for majority of Ugandans and have a great contribution to National Development plan (NDP), vision 2040 and Millennium Development Goals. According to Wetland Department, Ministry of Water and Environment, areas under wetlands have considerably reduced by about 10% since 1994 and this is a threat to the mentioned strategic plans. Understanding the effects of wetland conversion is important in the planning for sustainable management of natural resources and decision making. Mapping and monitoring these conversions is crucial in the preservation fragile ecosystems such as forests and wetlands in Uganda as well as sustainable use of these resources. Understanding the effects of wetland conversion on soil properties and water quality is paramount in informing ongoing debates as to whether or not significant parts of wetlands should be cleared for subsistence farming. The study is of greater importance to wetland conservation in regaining and maintaining the integrity of wetland ecosystems. It also acts as a benchmark for estimation of soil properties and water quality thereby encouraging conservation, sustainable management of land and increase in areas under wetlands as a potential policy approach under

REDD+.

1.6 Significance

The result from this study is required for policy making, business and administrative purposes. It is crucial in developing strategies that ensure sustainable use of the wetland and promotion of tourism activities which are a good source of foreign earnings for the country. It will also guide policy makers in designing policies that will protect fragile ecosystems from encroachment. The information from this study will as well guide the next generation environmental scientist in identifying research gaps and doing more research to address any other arising issues as pertains fragile ecosystems.

1.7 Scope and Time frame

The study was conducted in one of the districts in Eastern Uganda; Namutumba District and It mainly focused on land use changes with main emphasis on conversion of wetlands to crop fields and associated effects on quantitative soil properties and quality of water. The measured quantitative soil properties included soil pH, soil organic matter, nitrogen, phosphorous, potassium, calcium, magnesium, copper, zinc, boron, iron, manganese, cadmium, and lead. Water quality parameters measured were total hardness, total solids, total suspended solids, total dissolved solids, pH, turbidity, alkalinity, conductivity, lead, magnesium, sodium, calcium, chromium, iron, phosphates, chloride, cadmium, and sulphates. The research study took a period of thirteen months from June 2017 to July 2018.

CHAPTER TWO

LITERATURE REVIEW

2.1 Wetland environment in Uganda

Uganda's wetlands consist mostly of permanently flooded papyrus and grass swamp forests, upland bogs and areas of impeded drainage (MWE, 2007; Kumar and Kanaujia, 2014; Benstead and JoseJosé, 2001). These wetlands are widespread and complex. About 13 percent of the country, or approximately 29000 Sq.km, is covered by wetlands (swamps), of which about one-third is permanently flooded. In the south and west of the country, they form an extensive low gradient drainage system in steep V-shaped valley bottoms with a permanent core and relatively narrow seasonal wetland edges. In the north, they mainly consist of broad flooded plains. In the east, they exist as a small network of small vegetated valley bottoms in a slightly undulating landscape. The hydrology of wetlands in Uganda is still not well documented and understood; but what is certain is that they hold enormous amounts of freshwater reserves in excess of 20 km^3 of freshwater (MWE, 2005).

2.1.1 Importance of wetlands

Wetlands are ecosystems of great economic and ecological importance. The roles played by wetlands in Uganda have been recognized in many aspects including water storage, flood mitigation, regulation of flow water, groundwater recharge, improving water quality, water purification, erosion and sediment control, wastewater treatment act as breeding grounds for fish and also acting as habitats for wildlife (MWE, 2008). Wetlands provide food and other agricultural products such as fuel and fiber directly through agricultural production activities that take place within wetlands, such as rice paddies, coastal grazing marshes, recession agriculture and aquaculture in large flood plains, and cropping of small seasonal wetlands (Ramsar, 2015; Virginia, 2011). Wetlands also support agriculture indirectly, for example by providing fertile soils and reliable supplies of good quality water.

In many developing countries, local communities depend primarily on wetland. These communities utilize them for their livelihoods through reed harvesting, fishing, clay mining and agriculture (Adelaida, 2000).

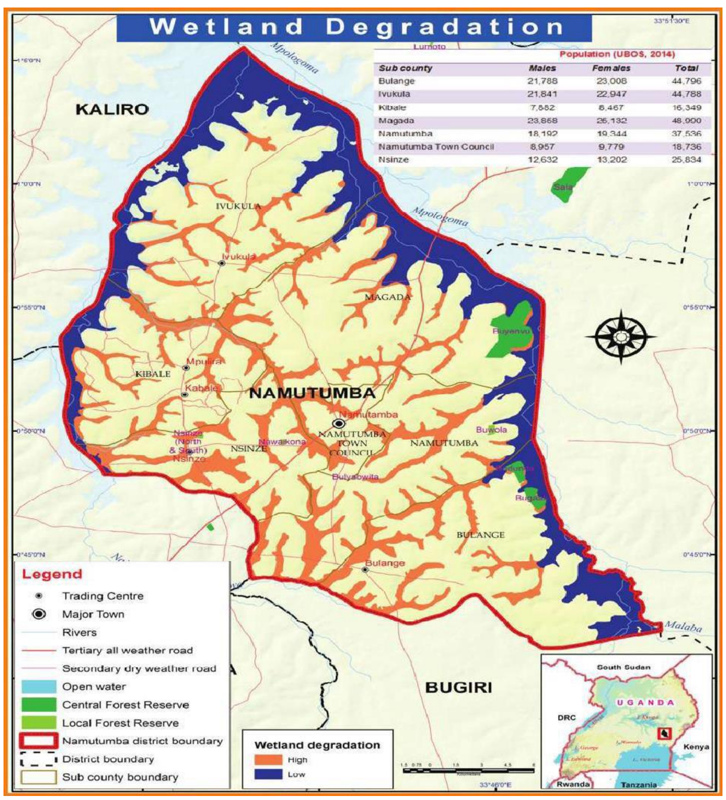
2.1.2 Wetland degradation and its effect in Uganda

In the last two decades, Uganda's freshwaters and wetlands have been exposed to industrial pollution and foreign invasion of species. Many wetlands are undergoing rapid conversion to other land uses while others are being over harvested (Ranger, 2015). It was estimated in the 1990s that an average of 7.3 percent of the original wetland in Uganda had been converted to other uses (WMD *et al*., 2009). This ranged from as high as 43.2 percent and 40.3 percent for Jinja and Kisoro districts respectively, to as low as 0 percent in districts such as Kalangala, Gulu, Kasese, and Hoima. Except for wetlands in protected areas, the rest, although protected by the national statute (1995), continue to be reclaimed and degraded. The major causes of degradation continue to be encroachment for agriculture and settlement, sand and clay mining, deforestation of swamp forests, and dumping garbage and swamp fires. Currently it is estimated that districts of Jinja and Mukono have now lost 80 percent and 15 percent respectively of their original wetland (Kasomo, 2003) and the general consensus is that the area under wetland coverage is still reducing. Figure 1 presents level of wetland degradation in Namutumba District.

2.1.3 Impact of agricultural activities on wetlands

Sustainable utilization of wetlands is very important for their survival while also helping the people that benefit from them to survive. Sustainability has to do with economic, ecological, and social aspects (Falvey, 2004). According to Brunt land commission sustainability is defined as using the available resources to meet the present needs without halting those of the future generations (World Commission of Environmental Development, 1987). From this definition, we can say wetland degradation is the process by which wetlands are used until they can longer maintain their uses of supporting and regulating the ecosystem services that are beneficial to both the present and future generations.

Sustainable agriculture in wetlands is the capacity to produce food regularly without causing acute damage to wetland ecosystem performance (Oki, 2021). One of the ways that may ensure sustainability is to acknowledge the factors that affect the stability and resilience of wetland soils. Unless done at sustainable levels, human based activities can ultimately lead to change in wetland vegetation and eventually their degradation. Agricultural activities that can disturb wetland functions and ecosystem services include conversion of wetlands to cultivated land or aquaculture and invasive plant and animal species (Verhoeven and Setter, 2010). The most important source of wetland degradation has been found to be mostly due to drainage for agricultural purposes which as a result causes over exploitation of the



wetland especially by farmers. Figure 1 presents level of wetland degradation in Namutumba District.

Figure 1: Levels of wetland degradation in Namutumba District (**Source:** Namutumba district of hazard risk and vulnerability profile Ministry Relief, Disaster Preparedness and Refugees).

2.2 Sustainable wetland management

Wetland conversion is not a new incident it is approximated that more than half of the wetlands in the world have vanished since the start of 20th Century with most losses happening in developed countries. However, wetland loss is on the rise in developing countries because conversion mainly for agriculture and urban development (Maltby, 1986; Farber and Constanza, 1987; Maltby, 1988) Continuous and unsustainable cultivation does not only cause loss of the wetlands it also leads to loss of soil fertility.

The processes leading to the formation of wetland soils involves special chemical conditions that are favored by waterlogged environments and these soils tend to turn acidic once water has been drained from the wetland (William et al., 2013). The physiochemical elements of water and biological processes determine the quality of water which in turn indicates the diversity of flora and fauna that water would support (Arora, 2017). The physical and chemical characteristics of water show seasonal fluctuations which can affect animals and plants. Temperature and pH also play important roles as many biological activities only occur within a narrow range (Sabater et al., 2002).

There is an increasing focus and mindset change on wetlands (Wilson, 1996). In some countries rates of loss are now slowing (Hollis, 1994) but this is not the case in most of the developing countries like Uganda. However, there is an increasing lack of widespread knowledge on the sustainable use of wetlands especially in developing countries and this can be attributed to lack of appreciation of the traditional values of these wetlands and desire for modernization (Panayotou,1999).

Globally the protection of wetlands is clearly defined in the Ramsar convention (Irvine et al., 2022). The main role of this body is conservation of international significance which have been identified and located in different countries also called Ramsar sites. The conversation and management of wetlands that are not defined with reference to Ramsar convention remains in the hands of national and local governments where they are located. Strategic management policies implemented at both national and local levels can play important roles in ensuring sustainability and survival of these wetland ecosystems. Implementation of such strategies requires up-to-date data that is collected regularly and over an extensive period of time in places where these wetlands face great threats from human population.

Uganda has one of the best wetland policies in the sub region but it still faces challenges trying to protect its wetlands. This could be due to a number of reasons one of which could be lack of sufficient capacity at local levels. Wetlands are among those natural resources whose management was delegated to districts and lower administrative units (MWE, 2008). The government of Uganda adopted a national environment policy in 1994 and one of the key policy objectives is to collect, analyze, store and disseminate reliable information relating to environmental management issues. This was strengthened in 1995 by the National Environment Act cap 153 which put in place the institutional framework that established the National Environment Management Authority (NEMA, 2008).

However, despite the efforts to produce environmental data there still exists data gaps and challenges, some of the noted ones include; inconsistent collection of data leading to missing data sets for some years thus making it difficult to make accurate predictions; lack of up-to-date data on soils, Uganda's major natural asset, topographical data, meteorological data etc. are all not up to date (Barbier et al., 1997).

2. 3 Wetland assessment and effective management

Evaluation of ecological status of wetlands in the affected areas is critical for effective management and conservation of these wetlands (Miranga, 2005). Ramsar convention outlines the ecological behavior of a wetland as the union of the ecosystem components (physical, chemical and biological parts of a wetland), processes (physical, chemical and biological changes or reactions occurring naturally in a wetland) and services (benefits that people receive from wetlands) that distinguish the wetland. In an effort to fill such a knowledge gap, this research will be done to assess the ecological impact that plants grown in wetlands have put on the wetlands with much effort being put on abiotic factors.

2.4 Land use and land cover change

Alawamy et al. (2020) indicated a decrease in natural Mediterranean forest which lost 9018 ha over 32 years, 39% of its total area, with the highest deforestation rate registered between 2010 and 2017 estimated at 513 ha. $year^{-1}$. They further noted that Orchards and rain-fed agriculture lands gained 4095 ha, which matches 55% of initial area, whereas the land under irrigated crops increased by 2266 ha, about 85% of the original area. They further indicated that the area of urban and built-up land in 2017 was more than double that of 1985 and achieved the highest urbanization rate between 2010 and 2017 at 203 ha.$year^{-1}$.

Siddhartho (2009) conducted a study to indicate the land use and land cover change dynamics in Kiskatinaw River Watershed, BC, Canada. His results revealed the dynamic nature of different forest types. He further noted an increase in built-up area and significant depletion of wetlands throughout the entire study period.

Swart (2016) detected land use changes that occurred in the Mau forest complex in Kenya between 1973 and 2013. She revealed a decline in the areas under forest and rangeland between 1973 and 2013. On the other hand, she noted an increase in areas under smallholder agriculture.

A study carried out by Cheruto *et al*. (2016) to detect land use changes in Makueni County, Kenya revealed an increase in areas under built up, water bodies and vegetation increased from 160.7 km^2, 1.1$km^2$and 2159.77 km^2 in 2000 to 644.57 km^2, 5.77 km^2 and 3893.27 km^2 in 2016 respectively. They further noted that croplands, evergreen forests, grasslands and bare-lands decreased during this period with evergreen forests decreasing the most from 39% coverage in 2000 to 17% coverage in 2016.

There was a decline in forest cover from 48.7149 Km^2 (71%) to 35.67852 Km2 (52%) in a study conducted by Mogosi (2015) to detect changes in land use in Nanyuki River Watershed. He also noted an increase in agriculture land by 5% in terms of coverage. Built up areas increased by 8% between 1985 (2.058376 Km^2) and 2015 (8.233504 Km^2.).

Mwanjalolo *et al*. (2018) evaluated the extent of historic, current and future land use systems in Uganda. They noted an increase in areas under subsistence agricultural and grasslands protected while the highest losses were seen in grasslands unprotected and woodland/forest with low livestock densities.

Malaki (2018), established land use and land cover changes that occurred in Nguruman watershed in Kenya between 1994 and 2014. He observed that forestlands decreased by 64% at the expanse of cropland which increased by 27% in Entasopia from 1994 to 2014. He further noted an expansion in forestland (4%) in Pakaise and a decline in cropland by 15%. He further indicated a decline in wetlands by 12% and 1% in both Pakaise and Entasopia respectively.

2.4 Effect of cultivation of wetlands on quantitative soil properties

Hedman (2019) revealed significant differences in organic carbon (OC), bulk density (BD) and soil pH among land use types; farmland, natural grasses, woodland and wetlands in the study conducted to determine the impacts of land use on wetland carbon storage and ecosystem services in Uganda. Wetland soils had higher amounts of OC, pH and lower BD compared to farmland, natural grasses and woodland.

Bruland *et al*. (2003) compared soils of an agricultural field, restored wetland and a non-riverine swamp forest and a high pocosin forest located at the Barra Farms Regional Wetland Mitigation Bank, a Carolina Bay complex in Cumberland County, North Carolina. Agricultural land had higher P contents compared to wetlands and restored wetlands. Wetlands had higher N compared to other ecosystems. Ca was higher in agricultural land and restored wetland compared to non-disturbed wetlands. Their results further indicated higher OC in wetlands compared to other ecosystems.

Lemt *et al*. (2014) determined the impact of wetland tillage on plant diversity and soil viability in South-

Bench District in South Western Ethiopia. Their results indicated that moisture content, clay content, organic carbon, total nitrogen, available phosphorus, cation exchange capacity (CEC), exchangeable K^+ and Na^+ were significantly lower while silt, pH and electric conductivity (EC) were significantly higher for cultivated sites compared to uncultivated sites. Their results further indicated no significant difference in

BD, sand, exchangeable Mg^{2+} and Ca^{2+} between cultivated and uncultivated sites.

Soil organic carbon was higher in uncultivated wetlands compared to paddy fields in a study conducted by Mujiyo *et al*. (2018) to establish the effect of organic paddy field system on soil physical, chemical and biological properties. Similarly, Arunrat (2020), revealed higher OC in uncultivated wetlands compared to sandy paddy fields of Northeast Thailand.

Available phosphorus was low across all the land use types (LUTs). Total nitrogen was generally low in most of the cultivated soils to moderate in the fallow soils. cation exchange capacity Cation exchange capacity CEC was low, while the exchangeable sodium percentage (ESP) was high (>5) in all the LUTs. The degradation results showed that most of the cultivated wetlands were very degraded compared to the reference (fallow) soils which were slightly degraded. Available P, Ca, and K were not significantly different among land use types. Soil pH ranged from moderately acidic to slightly alkaline with fallow soil having the highest value (Osinuga and Oyegoke, 2019).

In a study conducted by Lian *et al*. (2013) to establish the effect of land cover changes and the impacts of cultivation on soil properties in Shelihu wetland, Horqin Sandy Land, Northern China, cultivated wetlands were found to be with higher EC and silt and clay ratios, lower pH compared to soils in uncultivated wetlands. Their results further revealed that cultivated wetlands were seriously degraded with lower contents of SOC, TN and TP than uncultivated ones. They further indicated that SOC, TN content and EC decreased with the increase of cultivation age, while pH showed a reverse trend with significance at plough horizon.

Ewing *et al*. (2012) obtained remarkably greater amounts of extractable P, Ca, Mg, Mn, Zn and Cu in cultivated wetlands compared to the uncultivated ones and higher base concentration and pH in wetland soils in the study conducted to determine the effect agricultural production on morphological and chemical properties of wetland soils.

The carbon (C), nitrogen (N) and phosphorus (P) contrasts of a temperate wetland soil under continuous cultivation for 40 years (yrs) were assessed in the Sanjiang Plain, Northeast China by Wang et al. (2012). The results showed that OC and TN contents in each soil layer rapidly decreased after cultivation for 2-3 yrs. They further noted a decrease in soil total phosphorus (TP) stocks after cultivation of 5 yrs, and a gradual restoration to the original level after cultivation for a period of 17 yrs.

With the increase in restoration time, soil moisture, soil salinity, EC and soil particle size tended to decline, yet soil organic matter tended to increase in a study conducted by Sun *et al*. (2011) to determine the impact of restoration time and land use on soil properties in Changjiang River Estuary in China. Soil available phosphorus had a rising trend in the early reclamation period, and later declined after about 49 years of reclamation. They further noted a slight change in soil ammonia nitrogen, soil nitrate nitrogen and pH in distinct reclamation years.

Wang *et al*. (2014) determined the long-term effect of land reclamation on soil chemical properties of a Coastal Saline Marsh in Bohai Rim, Northern China. The results showed that long-term reclamation remarkably decreased OC and TN at the surface layer. They further noted no significant change in TP, an increment in soil pH after reclamation and a decrease in the composition of Na^{+}, Cl^{-} and SO_4^{2-}.

With time after reclamation in South-Eastern China, salt content, alkalinity, and particle size decreased, while organic matter content increased. A relatively stable state was reached within 10 years after reclamation for pH, about 30 years for organic matter, and 60 years for electrical conductivity, respectively (Wang *et al*., 2014).

In a study conducted by Zhao *et al*. (2020) to estimate the effects of modern land use types and conversions from wetland to paddy field on soil organic carbon ratios, dissolved organic carbon (DOC) increased 17% in built wetland and decreased 39% in fishponds, and the content of heavy ratios of organic carbon (HFOC) in constructed wetland and fishponds increased 50% and 8%, respectively, compared with that in natural wetlands at 0–20 cm. After the alteration of a wetland, the content of HFOC increased by 72% in the paddy fields and decreased 62% in the dry land, while the content of DOC and low fraction organic carbon (LFOC) decreased in both types. In the paddy fields, LFOC and HFOC content in the top-most 0.2 m of the soil layer was significantly higher compared to the layer below (from 0.2 to 0.6 m).

It can be concluded that most of the above studies were conducted in China with few studies in East Africa and in particular Uganda. None of the above studies incorporated the effect of seasons on quantitative soil properties (Hedman, 2019; Ewing *et al*., 2012; Wang *et al*., 2014, Zhao *et al*., 2020; Sun *et al*., 2011; Wang *et al*., 2012, Lian *et al*., 2013; Osinuga and Oyegoke, 2019; Arunrat, 2020 and Mujiyo *et al*., 2018). Similarly, none of the above studies determined the effect of cultivation of wetlands on heavy metals and most of the studies concentrated on OM, soil pH and macro nutrients. This study incorporated the effect of seasons, cultivation of wetlands on many quantities of soil properties including micro nutrients and heavy metal concentrations in selected wetlands in one of the districts; Namutumba in Uganda.

2.5 Effect of cultivation of wetlands on water quality

Bruland *et al*. (2003) determined the effects of agriculture and wetland reclamation on hydrology and water quality of a Carolina Bay complex. Water hydrology and quality of an agricultural field were compared, in a two-year-old restored wetland, and two reference ecosystems (a non-riverine swamp forest and a high pocosin forest located at the Barra Farms Regional Wetland Mitigation Bank, a Carolina Bay complex in Cumberland County, North Carolina. Mean concentration of phosphates and total P and nitrate were higher in agricultural land and much lower in restored wetland. Total nitrogen was highest in wetland ecosystems compared to cultivated land.

Uwimana *et al*. (2018) revealed higher total suspended solids, total N and P in cultivated fields compared to the uncultivated ones in a study conducted to determine the effects of conversion of wetlands to rice and fish farming on water quality in the valley bottoms of the Migina catchment in Southern Rwanda. They further noted that these results were connected with periods of farming activity.

Moreno-Mateos *et al*. (2009) carried out asurvey to determine the effect of wetland conversion on water quality in semi-arid areas. They found out that some of the disturbed wetlands had the highest amounts of TSS, sediments and nitrates. In their study, they also compared nutrients and sediments in artificial wetlands and natural ones and they found out that artificial wetlands transported more nutrients and sediments.

Temperature, pH, electrical conductivity and dissolved oxygen concentration decreased, and TSS increased with storm water increase. TN and TP accumulated in the catchment during the dry season and washed into the water courses during the early stages of the higher flows, with subsequent lower concentrations at the end of the rains due to dilution. Fishponds acted as temporal traps of TSS, TN and TP at the early stages of farming, and were a source of and TN and TP at the end of the farming period, in contrast to rice farming that generated sediments and nutrients early in the farming period and trapped them at the end of the farming season (Uwimana, 2019).

Total suspended solids (TSS), turbidity, TDS, electrical conductivity (EC), TH, pH and microbial activity that utilize E. coli as a standard test were remarkably higher in farmed wetlands compared to the unfarmed ones in a study conducted by Tumwesigye (2012) in Nyaruzinga wetland in South-Western Uganda. He further compared these results to both national and WHO guidelines and found that they were outlying the range proposed by both the national standard and World Health Organization (WHO) guidelines.

With the exception of Tumwesigye (2012), it can be concluded that most of the above studies were conducted in other countries other than Uganda (Bruland *et al*., 2003; Moreno-Mateos *et al*., 2009; Uwimana, 2018; 2019). None of the above studies incorporated the effect of seasons on water quality. This study incorporated the effect of seasons and determined the effect of cultivation of wetlands on most of the properties of water quality in Namutumba district in Uganda.

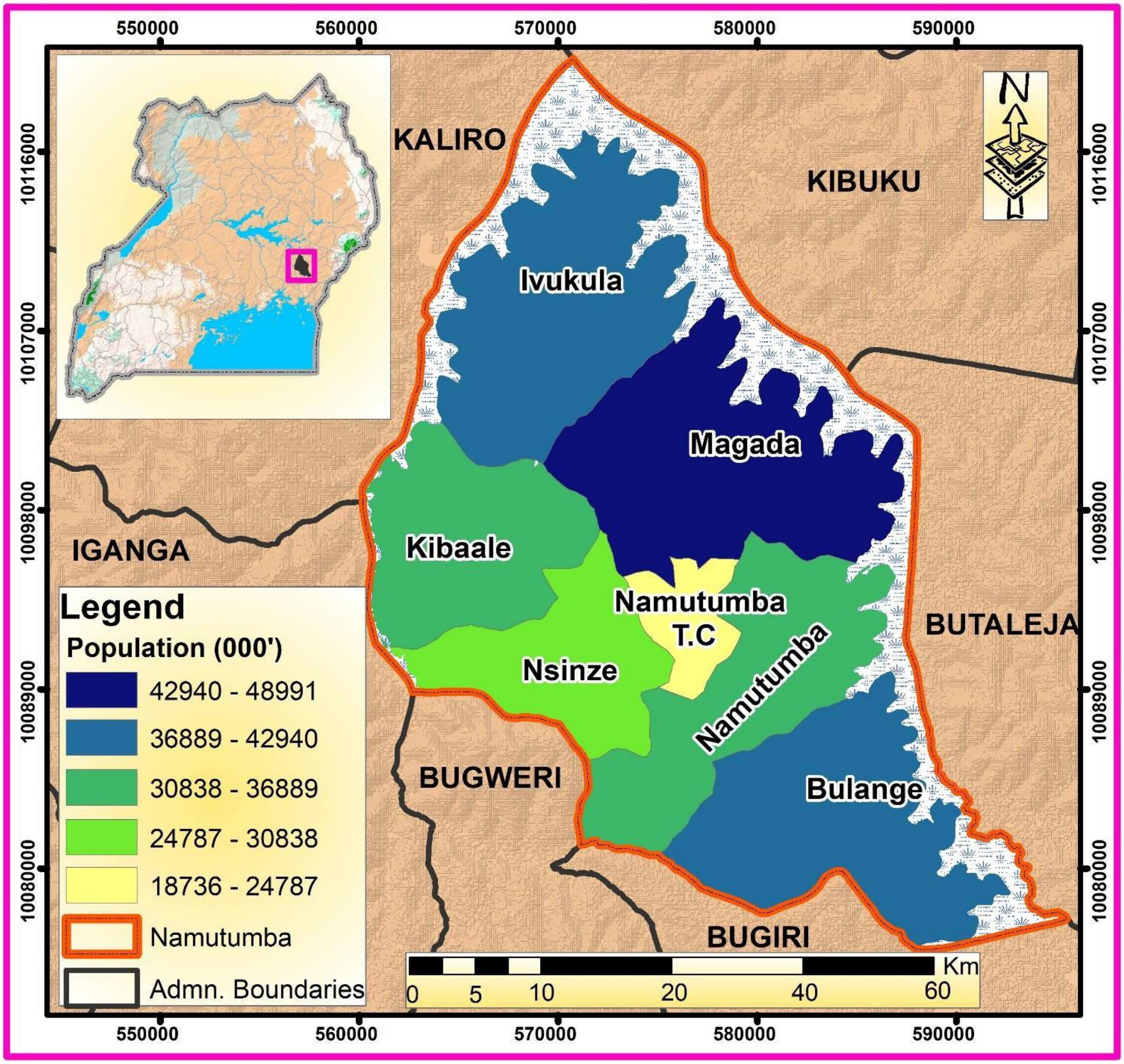


Figure 2: Population distribution in Namutumba District.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter entails different methods and approaches that were used to answer the specific objectives. The sub-titles under this chapter include; description of the study area, economic activities, geology and climate of the study area. Others include procedures and equipment used in soil and water sampling and laboratory analysis of soil and water samples.

3.2 Description of the study area

3.2.1 Location

Namutumba District is located in South-eastern part of Uganda and it is approximately 140 km from Kampala city. Namutumba District is bordered by Iganga District in the South, Bugiri in the South-East, Kaliro, Kibuku in the North and Butalejja in the East. The district Headquarters are located at formerly Saza Headquarters, Busiki County, Kaiti village. The district has a size of 801.87 sq.km most of which is land. The district has two small lakes located in Ivukula Sub-County. The total area covered by wetlands is 137.94 sq.km. The meteorological data from Namutumba district is typical of Eastern region of Uganda. There is tropical climate characterized by comparatively small variations in temperatures. The District has biannual season with first rains covering March to June and second rain August to November. The study location is presented in Figure 3

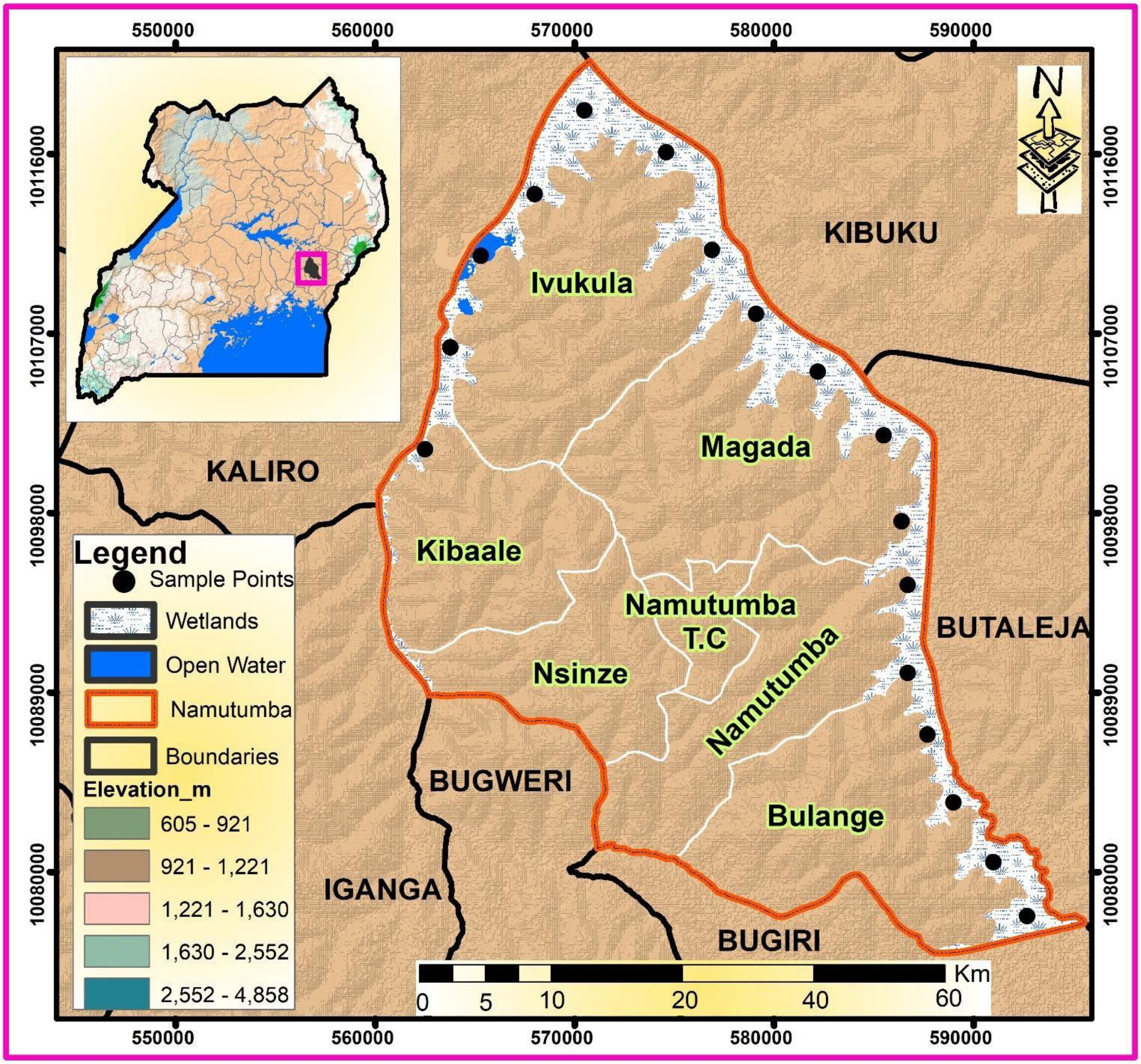


Figure 3: Study sites in Namutumba District

3.2.2 Economic activities

Agriculture is the main economic activity in the district and it is practiced by small producers growing crops like cotton, coffee, mainly for cash; and maize, beans, rice, groundnuts, sweet potatoes, cassava, millet, bananas which are the major food crops. Other crops include; simsim, soybeans, sunflower, vegetables and fruits. Over 80% of farmers practice subsistence farming in most cases production is not economically viable. Animals kept include; cattle, goats, sheep, pigs, rabbits, chicken, turkeys, ducks.

There is also tourism potential in the District with some different species of birds living along the Mpologoma river which are good for bird viewing. Other attractions include wetlands stretching from East to North-West of the District and there are rare situnga and reedbuck, vervet monkeys around these wetlands. Catfish and lungfish commonly known as Emale and Mamba respectively are also common. The rice fields also have a variety of bird life which include; ducks, yellow billed stock, open billed storks and cranes. There are also snakes such as the python and many others.

3.2.3 Climate

The meteorological data for Namutumba District is Typical of eastern region of Uganda. The District enjoys a tropical climate and is characterized by comparatively small seasonal variations in temperatures. The rain falls for 160 – 170 days each year with two peaks from March – May and October – November. The temperature ranges from 22^0 Celsius (C) to 27^0 C with an annual average of 25° C. The annual temperature range is 23 - 27° C. The mean annual rainfall is 1000 mm with a range from 900 mm - 1150 mm. The district is of bi-annual season with the 1st rains covering March-June and 2nd rains August –November.

3.2.4 Topography

The terrain upon which Namutumba District is located is that of remnant Busoga surfaces and valleys. Physiographic, it rises from lowlands of 1,167 meters to hilly surroundings of 1, 2249 meters above sea level. Elsewhere are valley sediments eroded from higher grounds, which form part of the District Basement Valley of varying gradients that separate the steep slopes of Namutumba District, these valleys form essential natural drains of the District downstream towards Mpologoma. Topography of Namutumba District is presented in Figure 4.

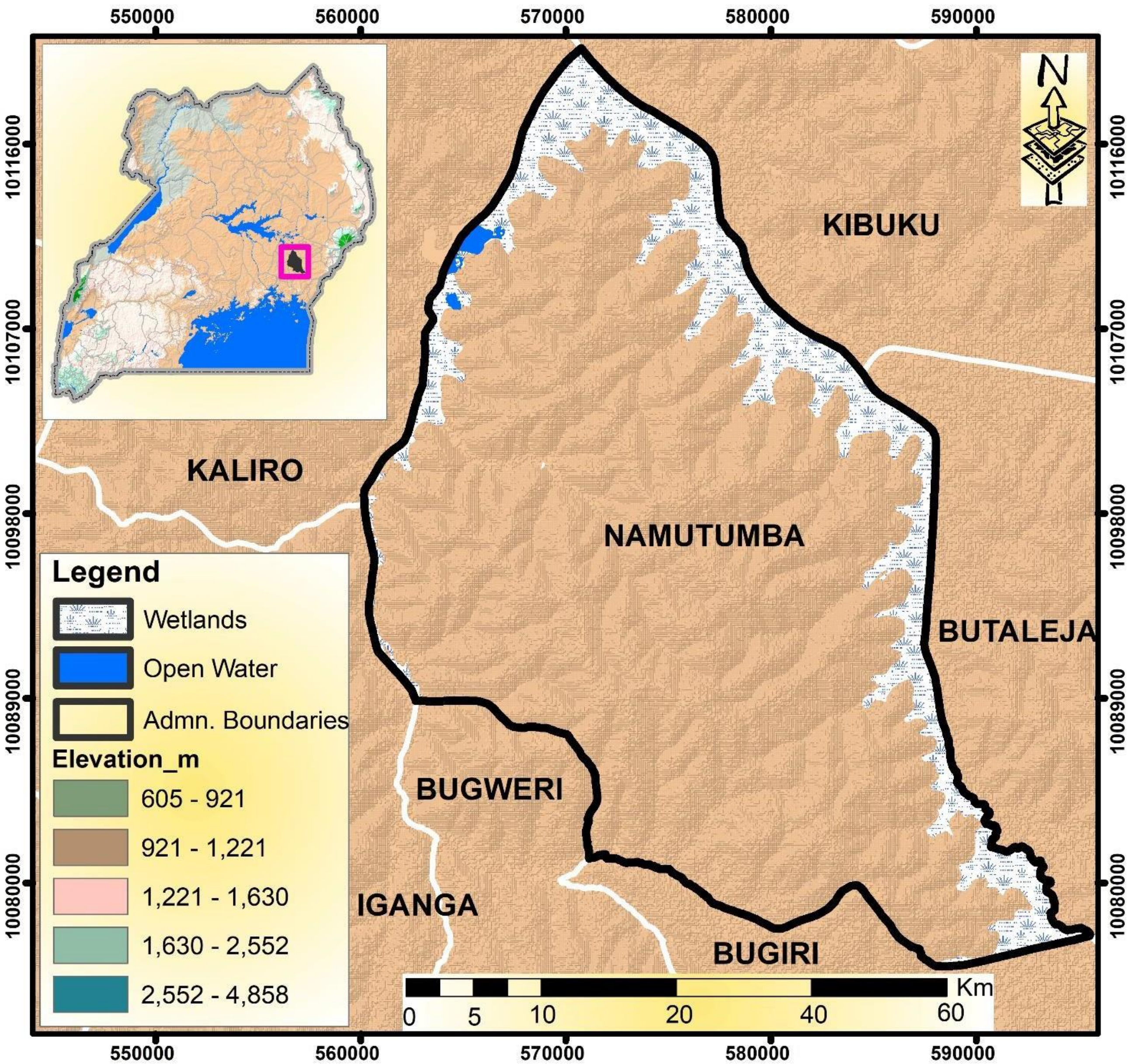


Figure 4: Elevation in Namutumba District

3.2.5 Geology and soils

The largest part of the District is underlain by un-differential gneisses formerly seen as part of the basement complex. Rhodi, Ferralitic and Nitisol are the predominant soil types with patches of Epi/Endo petricplinthsols superimposed on the Nitsols in isolated and very small areas. This soil type is of relatively high to moderate fertility, they are permeable, with a stable structure, and low erodibility, hence less prone to erosion.

Along the shores of Lake Victoria, the soils are mainly Hydromorphic. These are associated with Buganda Surface and Kabira Catena characterized by low to medium fertility. The Northern and Eastern parts are dominated by quartzite and laterites whose parent rock is the Buganda Catena, the remaining part being occupied by Lake sand and Granitic Rocks. Generally, all soil types in Namutumba District are of moderate stable structure, low in erodibility and high fertility, with ability to support a wide range of activities such as settlement, farming and forest establishment.

3.3 Land use change detection

3.3.1 Acquisition of data

Landsat TM and ETM images of path 170 & row 059 and path 171 & row 59 at a resolution of 30 m were downloaded from landsat.org for a period of 20 years (Table 3.1). The images with cloud cover between 10-20% were downloaded for years: 1988, 1998, 2008 and 2018 during the months of February, June, August and September. February and June falls in the first rainy season and August and September falls in the second rainy seasons of Uganda. These images were used to identify the existing land uses at that time. Hard copy maps e.g. vegetation maps and land use maps were obtained from the GIS unit at National Agricultural Research Laboratories was utilized to validate the results of the land use change analysis. For ground-truthing handheld Global Positioning System (GPS) was also used.

Table 3.1: Datasets used for analysis of land use change in Namutumba District. TM = thematic maps, m = meters and USGS = United States geological survey. Feb = February, Aug = August and Sep = September. (**Source**: student).

Dataset	Date of Acquisition	Path	Row	Resolution	Source
Landsat 4-5 TM C1 Level 1	18 Feb 1988	170	059	30 m x 30 m	USGS
	18 Feb 1988	171	059		
Landsat 4-5 TM C1 Level 1	22 June 1998	170	059	30 m x 30 m	USGS
	07 Aug 1998	171	059		
Landsat 4-5 TM C1 Level 1	19 Sep 2008	170	059	30 m x 30 m	USGS
	28 Sep 2008	171	059		
Landsat 8 OLI/TIRS C1 Level 1	24 Sep 2018	170	059	30 m x 30 m	USGS
	03 Feb 2018	171	059		

3.3.2 Image classification

Supervised classification procedures were implemented using Erdas 2010 image processing software to classify the Landsat images into established land cover classes using Maximum Likelihood Classification algorithm. Land use map of 1998 was used to verify the Landsat classification map. ArcGIS10.1 was used for the post classification change evaluation of the land cover maps to identify the land use changes that occurred between 1988 and 2018. The outcomes of these analyses were presented in terms of maps and the percentage changes in land use were presented in a tabular form.

3.3.3 Accuracy assessment

For the classification data to be useful in detection of land use changes, there is a need to perform an accuracy assessment. This helps to acknowledge and estimate the land use changes accurately. Accuracy assessment was conducted on the last image obtained i.e. 2018. This was done because at that time the existing land uses could be checked physically using ground truthing and validated with what was obtained from the image classification. In general, the accuracy was obtained by dividing the sum of the correctly classified units by the total number of the units.

3.3.4 Trend in land use change

The area (in km^2) covered by different land uses for each of the years; 1988, 1998, 2008 and 2018 were obtained from the GIS software and displayed in a tabular form. Using the total area of Namutumba District, these areas were converted into percentages.

3.4 Soil sampling and analysis

Representative soil samples were collected from cultivated and uncultivated wetlands from four different river systems of Naiyede, Namakoko, Mpologoma and Naigomba. Soil samples were collected using an auger from five (5) spots and mixed to obtain a representative sample. A total of six soil samples were collected using an auger at a depth of 0-20 cm in each of the river systems; 3 from the cultivated areas and 3 from the uncultivated ones. The main crops grown in wetlands (cultivated) were rice, maize and vegetables. Roots, gravels and stones were removed from these samples. They were bulked, labeled and transported to a soil laboratory for analysis at Makerere University for chemical analysis.

The soil samples were analyzed for soil pH, organic matter (OM), nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), boron (B), iron (Fe), manganese (Mn), cadmium (Cd) and lead (Pb). N was measured using Kjedahl procedures (Elliott et al., 1999). K was measured using flame photometer. Available P was determined using calorimetric method. Soil pH was measured using a pH meter in 1:2.5 soil water extract and available micronutrients; Cu, Fe, Mn, B and Zn was determined using Mehlich 3 method of extraction (Okalebo *et al*., 2002). The concentration of Pb and Cd was measured using flame atomic absorption spectrometer.

SOC was analyzed using wet oxidation method (Walkley-Black, 1934) and later converted to OM. Briefly, 1 g of each of the different size fractions were added into a 500 ml conical flask. The sample was oxidized using 10 ml of a 0.1667 M potassium dichromate ($K_2Cr_2O_7$) and 20 ml of sulphuric acid (H_2SO_4) containing silver sulphate (Ag_2SO_4). The solution was mixed thoroughly and allowed to react for 30 minutes (mins). The reaction mixture was diluted with 200 ml of deionized water and 10 ml of phosphoric acid (H_3PO_4) was added to it. 10 ml of sodium fluoride (NaF) solution and 2 ml of diphenylamine indicator was later added to the solution. The solution was titrated with standard 0.5 M iron sulphate (FeSO4) solution until a brilliant green color was obtained. A blank sample was as well run simultaneously. Percentage organic carbon was determined following equation 1.

Percentage organic carbon = (10 x (S-T) x 0.003 x 100) / (S x Wt.soil) ………………………………….(1)

where, S is the FeSO4 solution required for blank (ml), T is the FeSO4 solution required for the soil sample, Wt. soil is the weight of soil used, 3 is the equivalent weight (Eq W) of C (weight of C is 12, valency is 4 hence Eq W is 12/4 = 3), 0.003 is the weight of C (1000 ml 0.1667 M $K_2Cr_2O_7$ = 3 g C. Thus, 1 ml 0.1667 M $K_2Cr_2O_7$ = 0.003 g C). Organic carbon recovery is estimated to be about 77%. There for the actual amount of carbon was obtained by multiplying the obtained percentage C by 1.3.

3.5 Water sampling and analysis

Ten (10) representative water samples were collected differently from cultivated and uncultivated areas in each of the different river systems of Naiyede, Namakoko, Mpologoma and Naigomba. The samples were covered, labeled and immediately transported to the laboratory at College of Agricultural and Environmental Sciences, Makerere University for analysis. At the laboratory, the water samples were analyzed according to Standard methods for examination of water and wastewater following procedures described in APHA (1998).

The water samples were analyzed for both physical and chemical properties. Physical properties of water analyzed included colour, total hardness, total solids, total dissolved solids, total suspended solid and turbidity. The chemical properties of water analyzed were nitrates, pH, alkalinity, conductivity, lead, magnesium, sodium, calcium, chromium, iron, phosphates, chloride, cadmium and sulphates. pH was measured directly using a pH meter and conductivity using a conductivity meter. Turbidity levels were measured in Nephelometric units (NTUs) using the HACH 2100A turbidity meter. Colour (apparent colour) was determined using a spectrophotometer (DR 20800 model). Total nitrogen concentration was read directly using DR4000 spectrophotometer at 543 nm. Phosphorus and chlorides were determined calorimetrically method using visible spectrophotometer (model DR 3800-HACH). Sodium was determined using a flame photometer (Model CORNING M410).

3.6 Data analysis

R is a free software was used to analyze the data. R version 4.1.0 was used to calculate the mean, variance and standard error was used to assess the spread of the data. The mean of parameters (±SE) and one-way analysis of variance (ANOVA) followed by a post hoc multiple comparison (Tukey's test) was calculated to compare the mean values of observation based on the distribution of the sampling sites. ANOVA was used because the data was normally distributed and met the condition of equality of variances. The differences in mean values were considered significant if calculated p-values were < 0.05.

CHAPTER FOUR

RESULTS

4.0 Introduction

This chapter presents the results that were obtained to address the objectives of the study. The obtained results present the extent to which every specific objective of the study contributed towards understanding the effect of cultivation of wetlands on selected quantitative soil properties and water quality in Namutumba district in Uganda.

4.1 Results

4.1.1 Land uses identified

Table 4.1 presents the land uses identified in Namutumba District. From the image analysis and ground-truthing, the land uses identified in Namutumba District included woodland, farmland, bush land, built-up areas, wetlands and open water.

Table 4.1: Land uses identified in Namutumba District. (**Source:** student).

Land use type	Description
Woodland	Evergreen trees that naturally or artificially grown in reserved land along flatlands, riverbanks and hills.
Farmland	Food crops such as green vegetables, cereals, legumes and tubers for home consumption
Bush land	Evidenced with shrubs, thickets, figs and grasslands
Built-up areas	Evidenced with buildings, roads and communication structures.
Wetlands	Evidenced by both temporal and permanent swamps.
Open water	Evidenced by lakes, ponds, rivers and springs.

4.1.2 Areas covered by different land uses in Namutumba District in 1988, 1998, 2008 and 2018

The land uses changes that occurred in Namutumba District between 1988 and 2018 are presented in Table 4.2 and Figures; 4.1, 4.2, 4.3 and 4.4. In 1988, woodland occupied the largest area 37%, followed by wetland (12%), bush land (19%) and farmland (16%). 12% and 4% of the areas were under built-up areas and open water respectively. In 1998, the land covers with the largest areas were wetland, farmland, and bush land at 22%, 12%, and 15% respectively. The percentage of areas covered by woodland, built-up areas and open water were 35%, 12% and 3% respectively. Farmlands and bush land occupied the greatest areas in 2008 with percentage coverage of 34% and 22% respectively. The smallest area was under open water (1.4%). In 2018, farmlands and built-up areas had the biggest coverage of 36% and 26% respectively. Still open water had the small coverage (0.6%).

Table 4.2: Percentage in land use cover in Namutumba District between 1988 and 2018. LU/LC = land use/land cover, % = percentage covered by each of the land uses for the different years. Km^2 = kilometer squared (**Source:** Student).

LU/LC	**1988**		**1998**		**2008**		**2018**	
	Area (Km^2)	**%**	**Area (Km^2)**	**%**	**Area (Km^2)**	**%**	**Area (Km^2)**	**%**
Built-up	95.8	11.76	95.9	11.78	86.4	10.63	212.5	26.12
Bush land	154.5	18.99	121.4	14.92	180.2	22.16	84.8	10.42
Woodland	131.2	16.12	101.0	12.41	102.7	12.63	83.8	10.30
Open water	31.2	3.84	25.5	3.14	11.4	1.40	4.8	0.59
Farmland	98.6	12.11	182.8	22.46	280.3	34.44	288.9	35.50
Wetlands	302.3	37.16	287.1	35.29	152.5	18.74	138.8	17.06
TOTAL	**813.6**		**813.6**		**813.6**		**813.6**	

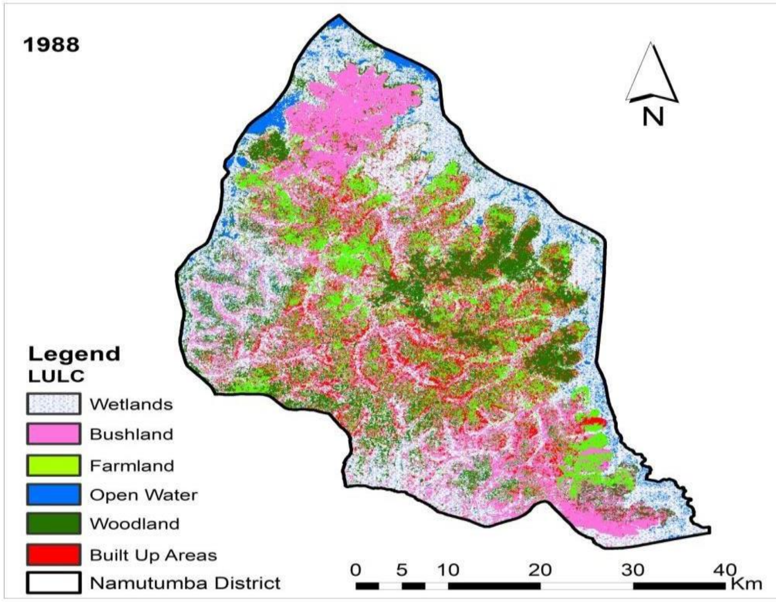


Figure 4.1: Land use in Namutumba District in 1988

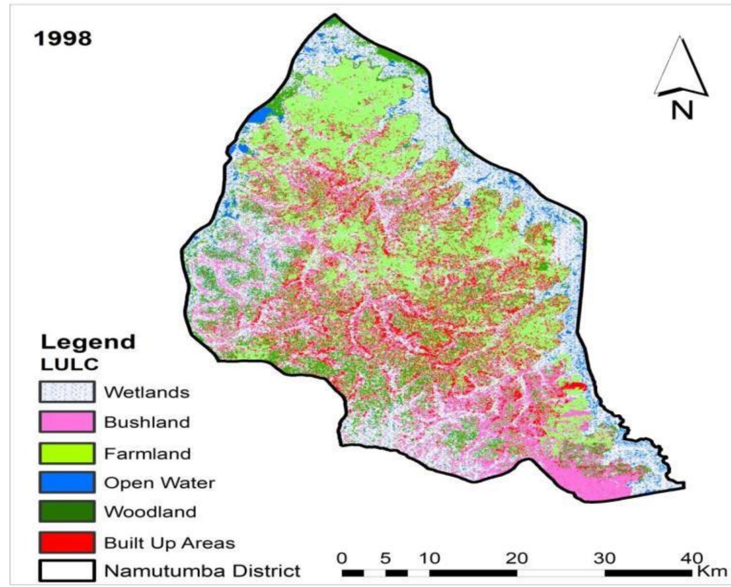


Figure 4.2: Land use in Namutumba District in 1998

(**Source:** Student)

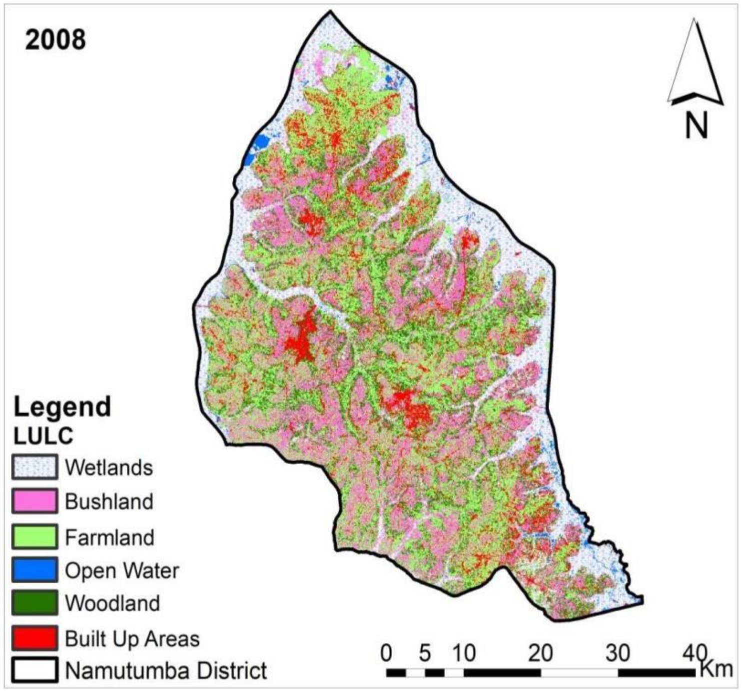


Figure 4.3: Land use in Namutumba District in 2008

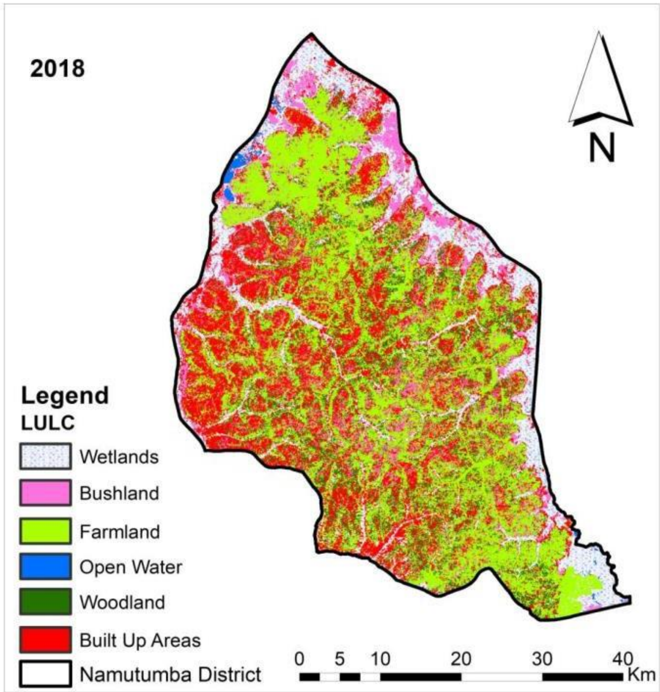


Figure 4.4: Land use in Namutumba District in 2018

(Source: Student)

4.1.3 Accuracy of the classified maps

Accuracy assessment was carried out for classified map of 2018 to examine the agreement between produced land use map of 2018 and what existed on the ground. The classified map of 2018 achieved overall accuracy value of 80% indicating that the land use map met the criteria for accurate classification. An accuracy of 60% and above is recommended for any classified maps (Congalton, 1991).

4.1.4 Trend in land use change

The trend in land use change between years; 1988 and 1998, 1998 and 2008 and 2008 and 2018 are presented in Table 4.3. Generally, there was a reduction in areas under open water throughout the years; 1988, 1998, 2008 and 20018. The highest reduction (1.74%) happened between 1998 and 2008. Built-up areas increased by 0.02% between 1988 and 1998. It further increased sharply by 15% between 2008 and 2018. Farmlands increased by 10% and 12% between 1988-1998 and 1998-2008 respectively. Conversion of wetlands to other land uses was rampant between 1998 and 2008. Areas covered by wetlands reduced by 17% between 1998 and 2008. Areas covered by bush land also reduced by 12% between 2008 and 2018.

Table 4.3: Percentage change in land use between 1988 and 2018. % = percentage change in land use. (**Source**: student). - = reduction in area coverage and + = increase in area coverage. * = significant.

Land uses	**1988-1998 (%)**	**1998-2008 (%)**	**2008-2018 (%)**
Built-up areas	0.02	-1.15	15.49*
Bush land	-4.07	7.24*	-11.74*
Woodland	-3.71	0.22	-2.33
Open water	-0.7	-1.74	-0.81
Farmland	10.35*	11.98*	1.06
Wetlands	-1.87	-16.55*	-1.68

4.1.5 Effect of cultivation of wetlands on selected quantitative soil properties

Tables; 4.4 and 4.5 present the average values of quantitative soil properties as affected by cultivation, and location respectively. Generally, cultivation of wetlands had a significant ($p<0.05$) effect on quantitative soil properties; pH, OM, N, P, Na, Cu and Cd. Cultivation of wetlands significantly ($p<0.05$) increased the amounts of P, Na and Cd in the soils with average values of 50.86 ppm, 0.17 $cmol_{(+)}$/kg soil and 0.06 ppm respectively in cultivated wetlands as compared to 18.58 ppm, 0.11 $cmol_{(+)}$/kg soil and 0.04 ppm respectively in uncultivated wetlands. On the other hand, there were significantly ($p<0.05$) lower average values of quantitative soil properties; pH, OM, N and Cu in cultivated wetlands (5.1, 2.25 %, 0.12 % and 1.19 ppm respectively) as compared to the uncultivated (5.6, 3.61 %, 0.19% and 1.54 ppm respectively). Quantitative soil properties; K, Ca, Mg, Zn, B, Fe, Mn and Pb were not significantly ($p>0.05$) affected by cultivation of wetlands.

River systems in different locations in Namutumba District significantly ($p<0.05$) affected quantitative soil properties; P, K, Ca, Zn, B and Cd. There was a significantly ($p<0.05$) higher average values of P and Ca (54.55 ppm and 8.37 $cmol_{(+)}$/kg soil respectively) in Mpologoma river system compared to other river systems. Similarly, Zn, K and B were significantly ($p<0.05$) higher in Namakoko river system with average values of 25.6 ppm, 0.85 $cmol_{(+)}$/kg soil and 3.73 ppm respectively as compared to other river systems. The average values of pH, OM, N, Na, Mg, Cu, Fe, Mn and Pb were not significantly ($p>0.05$) different across all the locations.

Table 4.4: Effect of cultivation on quantitative soil properties. Trt = treatment, Uncul = uncultivated wetland, Cul = cultivated wetland. Soil pH = acidity or alkalinity of soil, OM = organic matter (%), N = nitrogen (%), P = available phosphorus (ppm), K = potassium (cmol(+)/kg soil), Na = sodium (cmol(+)/kg soil), Ca = calcium (cmol(+)/kg soil), Mg = magnesium (cmol(+)/kg soil), Cu = copper (ppm), Zn = zinc (ppm), Fe = iron (ppm), Mn = manganese (ppm), Pb = lead (ppm) and Cd = cadmium (ppm). % = percentage, ppm = parts per million, $cmol_{(+)/}kg$ soil = centimole of positive charge per kilogram of soil. a and b = letters for separation of means. Means within a column followed by the same letter (a or b) are not significantly different at 5% level. a and b = letters used for separation of means. (**Source:** student).

Trt	pH	OM	N	P	K	Na	Ca	Mg	Cu	Zn	B	Fe	Mn	Pb	Cd
Uncul	5.6[a]	3.61[a]	0.19[a]	18.58[b]	0.71[a]	0.11[b]	7.21[a]	1.99[a]	1.54[a]	18.75[a]	3.18[a]	98.41[a]	32.49[a]	0.02[a]	0.04[b]
Cul	5.1[b]	2.25[b]	0.12[b]	50.86[a]	0.73[a]	0.17[a]	7.30[a]	2.36[a]	1.19[b]	20.70[a]	2.80[a]	98.37[a]	26.36[a]	0.02[a]	0.06[a]
p-value	*0.00*	*0.00*	*0.00*	*0.00*	*0.74*	*0.00*	*0.89*	*0.10*	*0.03*	*0.50*	*0.63*	*0.99*	*0.06*	*0.81*	*0.01*

Table 4.5: Effect of river systems on quantitative soil properties. Mp = Mpologoma, Ng = Naigomba, Ny = Naiyede and Na = Namakoko. Soil pH = acidity or alkalinity of soil, OM = organic matter (%), N = nitrogen (%), P = available phosphorous (ppm), K = potassium (cmol(+)/kg soil), Na = sodium (cmol(+)/kg soil), Ca = calcium (cmol(+)/kg soil), Mg = magnesium (cmol(+)/kg soil), Cu = copper (ppm), Zn = zinc (ppm), Fe = iron (ppm), Mn = manganese (ppm), Pb = lead (ppm) and Cd = cadmium (ppm). % = percentage, ppm = parts per million, $cmol_{(+)}$/kg soil = centimole of positive charge per kilogram of soil. Means within a column followed by the same letter (a or b) are not significantly different at 5% level. a and b = letters used for separation of means. (**Source:** student).

River systems	**pH**	**OM**	**N**	**P**	**K**	**Na**	**Ca**	**Mg**	**Cu**	**Zn**	**B**	**Fe**	**Mn**	**Pb**	**Cd**
Mp	5.3^{a}	2.40^{a}	0.15^{a}	54.55^{a}	0.76^{ab}	0.18^{a}	8.37^{a}	2.29^{a}	1.52^{a}	20.23^{ab}	3.42^{a}	105.68^{a}	27.08^{a}	0.04^{a}	0.04^{b}
Ng	5.2^{a}	3.00^{a}	0.15^{a}	24.57^{b}	0.65^{b}	0.12^{a}	7.00^{ab}	2.02^{a}	1.21^{a}	13.48^{b}	1.70^{b}	94.73^{a}	28.85^{a}	0.01^{a}	0.04^{ab}
Ny	5.2^{a}	3.05^{a}	0.16^{a}	27.90^{b}	0.62^{b}	0.13^{a}	5.80^{b}	1.98^{a}	1.33^{a}	19.58^{ab}	3.12^{a}	91.63^{a}	31.21^{a}	0.02^{a}	0.04^{b}
Na	5.6^{a}	3.29^{a}	0.16^{a}	31.85^{ab}	0.85^{a}	0.13^{a}	7.90^{a}	2.41^{a}	1.42^{a}	25.60^{a}	3.73^{a}	101.52^{a}	30.57^{a}	0.03^{a}	0.07^{a}
p-value	*0.155*	*0.33*	*0.98*	*0.05*	*0.083*	*0.31*	*0.01*	*0.47*	*0.60*	*0.02*	*0.01*	*0.46*	*0.82*	*0.23*	*0.07*

4.1.6 Effect of cultivation of wetland soils on quality of water in the nearby streams

The effect of cultivation of wetlands and river systems on water quality is presented in Tables 4.6 and 4.7. Cultivation of wetland soils significantly ($p<0.05$) affected water quality parameters; TDS, TSS, conductivity, Na, Ca, TH, Cl, SO_4^{2-} and PO_4^{3-}. On average, significantly ($p<0.05$) higher values of TDS, TSS, conductivity, Na, Ca, TH, Cl, SO_4^{2-} and PO_4^{3-} (3.16 mg/L, 0.62 mg/L, 127 µS/cm, 19.29 mg/L, 5.2 mg/L, 2.37 mg/L, 23.8 mg/L, 32.26 mg/Land 74.00 mg/L respectively) were recorded in water samples obtained from cultivated wetlands as compared to the uncultivated ones with an average values of 2.29 mg/L, 0.36 mg/L, 93.48 µS/cm, 12.48 mg/L, 1.91 mg/L, 1.58 mg/L, 13.72 mg/L, 19.54 mg/L and 15.13 mg/L respectively. Conversely, cultivation of wetlands did not significantly ($p>0.05$) affect water quality parameters; pH, Co, Tur, Alk, Pb, Mg, Cr, Fe, NO_3^- and Cd.

Most of the water quality parameters were not significantly ($p>0.05$) affected by river systems in different locations with the exception of pH, Co, Tur, TDS, TSS, Pb, Alk and Cr. Naiyede river system had significantly ($p<0.05$) higher values of pH and Alk (6.9 and 1.9 mg/L respectively) compared to other river systems. TDS, Cr and Tur were signifcanlty higher in Naigomba river system compared to other systems with average values of 3.38 mg/L, 0.19 mg/L and 0.77 mg/L respectively. Namakoko had significantly higher average values of Co and TSS (2.24 TUC and 0.65 mg/L respectively) compared to other river systems.

Table 4.6: Effect of cultivation of wetlands on water quality. Trt = treatment, Cul = cultivated wetlands, uncul = uncultivated wetlands. Co = color (TCU), concentration of H^+, Tur = turbidity (NTC), TDS = total dissolved solids (mg/L), TSS = total suspended solids (mg/L), Cond = conductivity (µS/cm), Alk = alkalinity (mg/L), Pb = lead (mg/L), Mg = magnesium (mg/L), Na = sodium (mg/L), Ca = calcium (mg/L), Cr = total chromium (mg/L), Fe = iron (mg/L), NO_3^- = nitrates (mg/L), Cl = chlorides (mg/L), Cd = cadmium (mg/L), SO_4^{2-} = sulphates (mg/L), PO_4^{3-} = phosphates (mg/L) and TH = total hardness (mg/L). Means in the same column followed by the same letter (a or b) are not significantly different at 5%. a and b = letters used for separation of means. (**Source:** student).

Trt	**pH**	**Co**	**Tur**	**TDS**	**TSS**	**Cond**	**Alk**	**Pb**	**Mg**	**Na**	**Ca**	**Cr**	**Fe**	**NO_3^-**	**Cl**	**Cd**	**SO_4^{2-}**	**PO_4^{3-}**	**TH**
Cul	6.7[a]	1.49[a]	0.40[a]	3.16[a]	0.62[a]	127.00[a]	1.50[a]	0.02[a]	1.30[a]	19.29[a]	5.20[a]	0.15[a]	0.20[a]	4.78[a]	23.8[a]	0.01[a]	32.26[a]	74.00[a]	2.37[a]
Uncul	6.5[a]	1.34[a]	0.46[a]	2.29[b]	0.36[b]	93.48[b]	0.97[a]	0.01[a]	1.04[a]	12.48[b]	1.91[b]	0.12[a]	0.14[a]	2.60[a]	13.72[b]	0.02[a]	19.54[b]	15.13[b]	1.58[b]
p-value	*0.38*	*0.62*	*0.79*	*0.04*	*0.03*	*0.02*	*0.117*	*0.36*	*0.12*	*0.01*	*0.03*	*0.20*	*0.15*	*0.07*	*0.01*	*0.44*	*0.03*	*0.00*	*0.01*

Table 4.9: Effect of river systems on water quality. Loc = location, Ny = Naiyede, Na = Namakoko, MP = Mpologoma and Ng =Naigomba, Co = color (TCU), concentration of H^+, Tur = turbidity (NTC), TDS = total dissolved solids (mg/L), TSS = total suspended solids (mg/L), Cond = conductivity (µS/cm), Alk = alkalinity (mg/L), Pb = lead (mg/L), Mg = magnesium (mg/L), Na = sodium (mg/L), Ca = calcium (mg/L), Cr = total chromium (mg/L), Fe = iron (mg/L), $NO3^-$ = nitrates (mg/L), Cl = chlorides (mg/L), Cd = cadmium (mg/L), $SO4^{2-}$ = sulphates (mg/L), $PO4^{3-}$ = phosphates (mg/L) and TH = total hardness (mg/L). Means in the same column followed by the same letter (a or b) are not significantly different at 5%. A and b are letters used for separation of means. (**Source**: student).

Location	**pH**	**Co**	**Tur**	**TDS**	**TSS**	**Cond**	**Alk**	**Pb**	**Mg**	**Na**	**Ca**	**Cr**	**Fe**	**NO_3^-**	**Cl**	**Cd**	**SO_4^2**	**PO_4^{3-}**	**TH**
Ny	6.9^{a}	0.91^{b}	0.14^{a}	2.16^{b}	0.42^{ab}	106.20^{a}	1.97^{a}	0.013^{ab}	1.07^{a}	15.18^{a}	4.66^{a}	0.13^{b}	0.22^{a}	4.21^{a}	19.83^{a}	0.01^{a}	33.5^{a}	40.75^{a}	1.70^{a}
Na	6.8^{a}	2.24^{a}	0.74^{a}	3.09^{ab}	0.65^{a}	130.00^{a}	1.19^{ab}	0.005^{b}	1.09^{a}	16.93^{a}	3.33^{a}	0.12^{b}	0.13^{a}	3.30^{a}	23.53^{a}	0.03^{a}	18.28^{a}	43.75^{a}	2.34^{a}
Mp	6.7^{ab}	1.15^{b}	0.07^{b}	2.27^{ab}	0.26^{b}	116.75^{a}	0.66^{b}	0.035^{a}	1.09^{a}	16.48^{a}	4.30^{a}	0.09^{b}	0.19^{a}	1.87^{a}	12.20^{a}	0.01^{a}	20.33^{a}	49.25^{a}	1.87^{a}
Ng	6.2^{ab}	1.36^{b}	0.77^{a}	3.38^{a}	0.62^{a}	88.00^{a}	1.14^{b}	0.010^{b}	1.43^{a}	14.95^{a}	1.95^{a}	0.19^{a}	0.13^{a}	5.38^{a}	19.48^{a}	0.01^{a}	31.50^{a}	44.50^{a}	2.00^{a}
p-value	*0.04*	*0.00*	*0.01*	*0.09*	*0.08*	*0.28*	*0.0281*	*0.08*	*0.342*	*0.96*	*0.65*	*0.01*	*0.072*	*0.14*	*0.33*	*0.93*	*0.18*	*0.99*	*0.57*

CHAPTER FIVE

DISCUSSION

5.1 Land use change that occurred in Namutumba District between 1988 and 2018

There was a reduction in areas under open water, wetlands, woodland and bush lands and an increase in built up areas and wetlands between 1988 and 2018. The population growth with consequent increase in the food demand forced people to open more land cultivation (Winkler et al., 2021). Many people could have engaged in agriculture for business to market in the nearby towns and cities. These results are in agreement with results obtained by Malaki (2018) in Nguruman sub-catchment in Kenya. However, it contrasts with results obtained by Cheruto *et al*. (2016) in Mkueni County in Kenya where they got a significant conversion of areas under forests to bushlands.

The results from the study further indicated an increase in areas covered by farmlands. The increase in farmlands can still be explained by an increase in population. Still, population growth with consequent increase in the food demand could have forced people to convert other land uses into farmlands. These results are in line with results obtained by Alawamy *et al*. (2020), Swart (2016), Mwanjalolo *et al*. (2018), Mogosi (2015) and Malaki (2018).

There was an increase in built up areas. This can be explained by population growth which required the construction of more houses to accommodate the growing number of families. Studies in other parts of the world also obtained similar results. Alawamy *et al*. (2020) in the region of Al- Jabal Al-Akhdar in Libya, Siddhartho (2009) in Kiskatinaw river watershed and Cheruto *et al*. (2016) in their study in Makueni county, Kenya obtained similar results. Areas under open water also declined (table 4.3). This is attributed to an increase in the number of people leading to increase in the demand of safe water for drinking and water for other uses. This led to drilling of underground water in many areas and there for reduction in areas under open water. The results are in conformity with results obtained by Malaki (2018) in Nguruman catchment in Kenya.

5.2 Effect of cultivation of wetlands on quantitative soil properties

Cultivation of wetlands affected quantitative soil properties; pH, OM, N, P, Na, Cu, Mn and Cd. Cultivation of wetland soils decreased soil pH, OM, N, Cu and Mn. However, amounts of P, Na and Cd were increased in the soils of wetlands as a result of cultivation. Cultivation of wetlands did not affect Ca and Mg. The decrease in OM could be attributed to OM mineralization. Cultivation exposes OM to aerobic conditions and therefore enhances the process of organic carbon mineralization leading to a decline in soil organic carbon (SOC) gradually and ultimately a decrease in OM (Ogle et al., 2005). These results are in conformity with studies conducted by Mujiyo *et al.* (2018), Arunrat (2020), Hedman (2019), Lian *et al*. (2013), Wang *et al*. (2012) and Wang *et al*. (2014). They obtained lower OM contents in soils of cultivated wetlands.

Similarly, the decrease in N, Cu and Mn could be associated with decomposition of OM. Decomposition of OM leads to release of nutrients e.g. N, Cu, Mn and others in the soil. The nutrients released migrate between different ecosystems and therefore a reduction of these nutrients in the soil. These results are in conformity with studies conducted by Mujiyo *et al.* (2018), Arunrat (2020), Hedman (2019), Lian *et al*. (2013), Wang *et al*. (2012) and Wang *et al*. (2014) who obtained lower OC in cultivated soils of the wetlands in North-East China and South-East China respectively. In contrast, Ewing *et al*. (2012) obtained greater values of Cu in soils of cultivated wetlands in their study in Carolina Bay because farmers were using farmers were using inputs containing a lot of Cu.

A decrease in soil pH could be connected to loss of OM due to rapid mineralization processes as indicated above, removal of soil nutrients and application of inorganic fertilizers such as nitrogenous fertilizers. These results are in agreement with studies conducted by Mujiyo *et al.* (2018), Arunrat (2020), Hedman (2019), Lian *et al*. (2013), Wang *et al*. (2012) and Wang *et al*. (2014) who obtained lower OM in soils of cultivated wetlands.

The increase in P could be associated with application of organic and inorganic fertilizers. The management options for crops in these cultivated wetlands could be associated with application of pesticides and other chemicals for management of pests and diseases and sometimes spraying with herbicides to control weeds. The application of these chemicals leads to increase in some toxic elements such as cadmium, arsenic, and selenium in the soil. The increase in Na and Cd in cultivated soils could be attributed to application of chemicals for pests and disease management and weed control. These results are in conformance with results obtained by Ewing *et al*. (2012) in Carolina Bay, South-Eastern and North Carolina. However, it contrasts results obtained by Bruland *et al*. (2003) in Carolina Bay and Lian *et al*. (2013) in Northern China who revealed a reduction in amounts of P in cultivated wetlands.

The no difference in Ca and Mg in cultivated and uncultivated soils could be associated with the presence of the same parent materials in the study areas and of the same weathering rate. Much as cultivated wetlands could have had lower amounts of Ca and Mg, probably the exposure of the parent materials to weathering factors was not enough to cause a difference in the amounts of Ca and Mg. Moreover, weathering takes a long term and probably, the wetlands could have been cultivated for a short term and therefore minimal exposure to weathering factors. The results are in correspondence with results obtained by Bruland *et al*. (2020). They revealed higher amounts of Ca in soils of cultivated wetlands compared to soils of uncultivated wetlands. However, it contrasts results obtained by Osinguga and Oyegoke (2019) who obtained an increase in Ca and Mg in cultivated wetlands.

Table 4.5 shows that P, K, Ca, Zn and Cd differed among river systems; Mpologoma, Naigomba, Naiyede and Namakoko. Higher values of P and Ca were recorded in soils of Mpologoma. Similarly, significantly higher values of K, Zn and Cd were observed in soils of Namakoko. The higher amounts of P and Ca in the Mpologoma area might be associated with the presence of rocks that contain minerals P and Ca in the area.

P and Ca are mainly obtained from the weathering of rocks which act as parent materials for these elements.

Namakoko area has higher amounts of K and Zn and these could be associated with decomposition of organic matter. The higher amounts of Cd could be associated with the use of chemicals for managing pests and diseases and weeds. This data is in conformity with studies conducted by Wang *et al*. (2012) and Wang *et al*. (2014).

5.3 Effect of cultivation of wetlands on quality of water

Cultivation of wetlands affected the properties of water quality such as TDS, TSS, TH, conductivity, Na, Ca, Cl, SO_4^{2-}, and PO_4^{3-}. TDS, TSS, TH, conductivity, Na, Ca, Cl, SO_4^{2-}, and PO_4^{3-} were higher in water samples collected from cultivated wetlands compared to the uncultivated ones (Table 4.6).

The higher amounts of TDS, TSS and TH could be associated with a lot of soil disturbance. Cultivation of soil breaks soil particles; sand, silt and clay and this leads to some solids remaining suspended in the water. The breaking of soil particles also exposes some minerals especially bonded to clay to break and dissolve in the water. The increase in other minerals such as Ca, Cl, SO_4^{2-}, and PO_4^{3-} could be associated with weathering of rock minerals. Cultivation exposes the soil and rock minerals to factors that affect weathering such rainfall, temperature and etc. These results are in conformity with studies conducted by Uwimana (2018; 2019) in Rwanda and Brudland *et al*. (2013) in Carolina Bay complex.

Table 4.7 indicated that the quality of water significantly varied in the wetlands situated in different locations. Colour, pH, turbidity, TDS, TSS, alkalinity, Pb and Cr were significantly different among locations. The increase in colour, turbidity, TDS and TSS in Namakoko and Naigomba could be associated with a lot of soil disturbance and probably, the areas around Namakoko and Naigomba could be having bare land with agricultural activities taking place on land close to the wetlands. Namakoko area could also be associated dominantly with clayey soils which makes it dissolved in water causing the obtained colour and increasing the amounts of TSS in the water. The increase in Cr and Pb in Naigomba and Mpologoma respectively could be associated with the use of chemicals for managing weeds, pests and diseases. These results were similar to results obtained by Uwimana (2018; 2019), Tumwesigye (2012) and Brudland *et al*. (2013) in their study to evaluate the effect of wetland conversion on water quality in Rwanda, Uganda and Carolina Bay complex respectively.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study established the land use changes that occurred in Namutumba District between years; 1988 and 2018 and determined the effect of cultivation of wetlands on selected quantitative soil properties and water quality. It can be concluded that areal coverage under open water, wetlands, woodland and bush lands reduced between 1988 and 2018 due to the expansion of farmlands. There was an increase in built up areas and wetlands between 1988 and 2018 due to increase in population. Cultivation of wetlands significantly increased the amounts of P, Na and Cd due to application of agro-chemicals and decreased amounts of quantitative soil properties; pH, OM, N and Cu due to break down of organic matter. Cultivation of wetlands increased water quality parameters; TDS, TSS, conductivity, Na, Ca, Cl, SO_4^{2-}, PO_4^{3-} and TH due to disturbance of soil structure and application of agro-chemicals. Recommendations

Based on the study, the following can be recommended:

1. The results of study to be used by local government officials to draft by-laws for protecting wetlands from degradation and educate the communities on the dangers of growing crops and application of chemicals on fragile ecosystems such as wetlands
2. The results of the study to be used by policy makers in designing policies from protecting wetlands from encroachment and degradation
3. Future generation environmental scientists to focus their research on the following research areas:
    - Processes that lead to increase in the amounts of Na and Cd in soils and water samples of cultivated wetland,
    - Pattern of change of wetlands to other land uses and the rate of change of quantitative soil and water properties,

- Effect of conversion of other stable ecosystems such as bush land and wood lands on quantitative soil properties,
- Effect of lack of farmer information on wetland degradation
- Validate these results by doing similar study on other wetlands in the district or nearby districts or any other agro-ecological zone,
- Compare the effect of conversion of wetlands on soil and water properties per soil type.

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APPENDICES

Appendix 1: Photograph of rice field in Namutumba wetland.

Appendix 2: Field visit to Namutumba wetland.