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DEPARTMENT OF CIVIL ENGINEERING

OPTION OF LAND SURVEYING

FINAL YEAR PROJECT REPORT.

THE IMPACT OF LAND USE AND LAND COVER (LULC) CHANGE ON WATER RESOURCES AND ITS IMPLICATION FOR SMALLHOLDER FARMERS IN RWANDA.

A CASE STUDY OF LAKE CYOHOHA NORTH (2013-2023)

Research proposal submitted in partial fulfilment of the requirements for the Award of advanced diploma

In land surveying.

Presented by:

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Under the guidance of:

Dr. Claire DUSABEMARIYA

Kigali, October 2024

DECLARATION OF ORIGINALITY

I, **HATEGEKIMANA Jean Bosco** do hereby declare that the work presented in this dissertation is my own contribution to the best of my knowledge. The same work has never been submitted to any other University or Institution. I, therefore declare that this work is my own for the partial fulfilment of the award ofthe advanced diploma in civil engineering department, land surveying option at ULK Polytechnic Institute.

The candidate's names: **HATEGEKIMANA Jean Bosco**

Signature of the candidate: ………………………………….

Date of submission: ………..…………………….…………...

APPROVAL

This is to certify that this dissertation work entitled "**THE IMPACT OF LAND USE AND LAND COVER (LULC) CHANGE ON WATER RESOURCES AND ITS IMPLICATION FOR SMALLHOLDER FARMERS IN RWANDA. A CASE STUDY OF LAKE CYOHOHA NORTH (2013-2023)"** is an original study conducted by **HATEGEKIMANA Jean Bosco** under my supervision and guidance.

The supervisor's names: **Dr. Claire DUSABEMARIYA**

Signature of the supervisor: …………………………….

Submission date: ………..……………………..…………

DEDICATION

I dedicate this project to:

2. Almighty God
3. My family

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This Thesis has benefited greatly from substantial inputs, guidance and comments from many people and institutions.

First of all, I would like to thank to the Almighty God for giving the wisdom and granting me resources whether financial and non-financial that has made a great contribution to this research project and my education in general.

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May God bless you all!!!

HATEGEKIMANA Jean Bosco

ABSTRACT

This study investigates the impact of land use and land cover (LULC) changes on Lake Cyohoha and their implications for smallholder farmers in Rwanda. Specifically, it examines the driving factors behind these changes from 2013 to 2023, assesses the extent of the changes, and evaluates their effects on local farmers. Results indicate that primary drivers of LULC change include infrastructure and agricultural expansion, influenced by political, economic, technological, demographic, environmental, and cultural factors.

In 2013, the catchment was predominantly agricultural, covering 60.3% of the area (4,694.9 ha), while water bodies accounted for 30.3% (2,358.87 ha), residential areas for 8.2% (632.5 ha), and healthy vegetation for 1.2% (97.5 ha). By 2023, agriculture had increased to 73.5% (5,721.9 ha), while water bodies and residential areas had decreased, showing substantial transformation. These findings underscore the need for sustainable LULC practices to support ecological balance and protect smallholder farmers' livelihoods in the Lake Cyohoha region."

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LIST OF ABBREVIATIONS

AIC	Appraisal Institute of Canada
BDDP	Bugesera District Development Plan
CBA	Critical Biodiversity Area
CGIS	Canada Geographic Information System
DEMP	Decentralization and Environment Management Project
DEO	District Environment Officer
DPSIR	Drivers-Pressures-State-Impact-Response
EEA	European Economic Area
EICV	Enquête Intégrale sur les Conditions de Vie
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
EU	European Union
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GGGI	Global Green Growth Institute

GoR	Government of Rwanda
GWP	Global Water Partnership
HGS	Home Grown Solutions
HH	Household
IDP	Integrated Development Project
LDCF	Least Developed Countries Fund
LUC	Land Use Consolidation
LULC	Land Use and Land Cover
MINAGRI	Ministry of Agriculture and Animal Resources
MINECOFIN	Ministry of Finance and Economic Planning
MINIRENA	Ministry of Environment
MOH	Ministry of Health
NGO	Non-governmental Organization
NISR	National Institute of Statistics of Rwanda
NYEP	National Youth Environment Project
OECD	Organization for Economic Co-operation and Development
PAUWES	Pan African University Institute of Water and Energy Sciences
RAB	Rwanda Agriculture Board
REMA	Rwanda Environment Management Authority
RGB	Rwanda Governance Board
RICA	Rwanda Institute for Conservation Agriculture

CHAPTER I: GENERAL INTRODUCTION

1.1. Introduction to the study

This chapter highlights the background of the study, statement of the problem, purpose of the study, objective of the study, research questions, research hypotheses, scope of the study, significance of the study, research methodology and lastly the structure of the study.

1.2. Background of the study

The world urban population has been growing at unprecedented rates over the past decades. According to the 2018 Revision of World Urbanization Prospects, 30% of the world's population was urban in 1950, today it is more than 55%, and it is estimated that in 2050, 68% of the world's population will be urban (Rujoiu-Mare & Mihai, 2016). Further analysis indicates that by 2050, population growth and urbanization will increase the world's urban population by 2.5 billion people and 90% of this increase will be concentrated in Africa and Asia (Li et al., 2010). The prospect of living in urban areas is often associated with better infrastructure, access to jobs and better health, education, transport, and social services. Such perceptions lead to rapid rural to urban migration which contributes to urban population growth and increases the demand for housing, and other urban land uses (Ola-Ade et al., 2021).

United Nations shows that low income and lower-middle-income countries will face challenges to meet the population demand. If not managed and properly planned, urban growth can lead to severe issues such as inadequate infrastructure, environmental degradation, and housing and transport shortages which pose adverse effects on the environment and increase pressure on water resources. In Rwanda, the implementation of six secondary cities has increased the pace of urbanization rate to 9% posing economic pressure in the distribution of wealth and economic opportunities. Despite the effects on environment and water resources, the policy of Rwanda provides an opportunity for intervention to promote a more inclusive development approach (Nsanzimfura, 2020)

Bugesera District Development Plan (2013-2023) reveals that the District is experiencing significant population growth, limited access to socioeconomic infrastructures, increasing household numbers, high levels of migration, urbanization, infrastructure development, and agricultural expansion and intensification (Leju et al., 2019). These trends have consequently triggered changes in LULC and incited issues such as urban extension, limited public access to resources, land degradation, and climate change. Furthermore, the issues surrounding LULC in the District emanate from past repeated drought coupled with unsustainable land-use practices resulted in degradation of water resources that left lake Cyohoha north likely to disappear (Maletta, 2020).

This poses a challenge to the government which strives for a sustainable nation that safeguards democracy by providing basic access to services, managing limited resources and advancing effective and efficient integrated planning whilst to maintain ecosystem functions (GGGI, 2015). Understanding drivers of LULC change and analysing how various factors influence LULC is vital in meeting this challenge (Landry et al., 2017).

Tools which integrate and evaluate diverse factors of LULC change can be used to guide planners in making decisions that are more informed and hence, achieve a balance between urban growth, intensive agriculture, and preservation of the natural environment. Some countries have created and adapted such tools as computer models which can assist in exploring the consequences of policies, human behaviour and other drivers on LULC patterns (Li et al., 2010). Remote sensing and geographical information system offer essential tools which can assist humans in making more informed decisions. The rationale for using remote sensing is to manage large amounts of data from widely dispersed locations effectively at much shorter time intervals, significantly reduced costs, and what is more, getting simultaneous observations covering vast areas. This research uses this approach to study the impact LULC change has on Lake Cyohoha North to address a particularly suitable land-use system (Hatami, 2018).

1.3.Problem statement

Lake Cyohoha faces significant water quality degradation, driven by changes in land use and agricultural practices in the surrounding catchment. Intensive farming methods, including the use of fertilizers and pesticides, have led to soil erosion and nutrient runoff, which contribute to excessive growth of aquatic weeds, such as water hyacinth. These invasive plants disrupt the lake's ecosystem, reducing water quality and biodiversity.

Additionally, the cultivation of buffer zones around the lake has removed natural barriers like papyrus, which previously helped filter pollutants and control erosion. Without these protective barriers, sediment and contaminants flow directly into the lake, exacerbating water quality issues and impacting fish populations and smallholder farming livelihoods.

The urgency of these environmental challenges calls for immediate action to protect Lake Cyohoha's resources. Addressing these issues is critical not only for preserving local biodiversity but also for supporting sustainable agricultural practices that benefit smallholder farmers and contribute to regional food security Purpose of the study**.** The purpose of this study is to assess the effects of land use and land cover change (LULC) on Lake Cyohoha and its implication for smallholder farmers in Rwanda. In addition, this study is carried out in partial fulfilment of the requirements for the award of advanced diploma in land surveying.

1.5. Objective of the study

1.5.1. Main objective

This study seeks to investigate the effects of land use and land cover change (LULC) on Lake Cyohoha and its implication for smallholder farmers in Rwanda.

1.5.2. Specific objectives

This project's specific objectives were as follows:

a) To determine the driving factors of LULC change in the Lake Cyohoha catchment from 2013 to 2023

b) "To analyze the changes in land use and land cover (LULC) in the Lake Cyohoha catchment from 2013 to 2023."

c) To conduct the impacts of LULC change in the Lake Cyohoha catchment on Smallholder farmers from 2013 to 2023,

1.6. Research questions

Based on the project's serviceability and functionality, answers to the following research questions will be offered in order to fulfil the above particular objectives.

a) To determine the driving factors influencing land use and land cover (LULC) changes in the Lake Cyohoha catchment from 2013 to 2023.

b) To analyze the changes in land use and land cover (LULC) in the Lake Cyohoha catchment from 2013 to 2023.

c) To assess the impacts of LULC changes in the Lake Cyohoha catchment on smallholder farmers from 2013 to 2023.**1.7. Scope of study**

This study was delimited in terms of space, content, domain and time. In terms of space, this study will be delimited in the Lake Cyohoha catchment. In terms of domain, the study will be delimited in the domain of land surveying. In terms of time, this study will be carried out in a period of 2013 -2023.

1.8. Significance of the study

This research will help the researcher to get some information about the effects of land use and land cover change (LULC) on Lake Cyohoha **a**nd its implication for smallholder farmers in Rwanda. This study will help the researcher as land surveyor to get advanced diploma certificate in land surveying. Further researchers will use the results of the present research in the conduction of related studies in the domain of about the effects of land use and land cover change (LULC). This study will help an institution to gain another reference book in land surveying option for future students doing final year dissertation in the same domain.

A review of academic literature has revealed that no attempts have been made to implement LULC change models at a regional level in Rwanda. This is, however, a significant scale to analyze the factors which drive LULC change (e.g., governance) operating at this level. LULC changes operating at regional levels have significant impacts on catchment-scale issues such as climate change and food security. Furthermore, processes which contribute to LULC change do not operate in isolation, various factors operate at different scales, and there is a need to analyze higher-level processes which influence LULC change. This study will, therefore, fill the gap of LULC change at a catchment scale in a Rwandan context.

This project will further help government for reinforcing policies governing agriculture for the protection and management of water resources to achieve the goals of economic development and poverty reduction strategy to foster and remain on the path to sustainable water resources management and achieve the aspirations of the 2020 vision (T. R. of Rwanda, 2011; The Republic of Rwanda, 2012). The research will, therefore, contribute to building the capacity of farmers in Lake Cyohoha catchment on soil conservation and best water management practices to sustainably prevent the degradation of this water resource. The contribution of this study was of interest to planners and researchers because it will: Augment the existing practical and theoretical knowledge based on LULC development and change. Infuse more knowledge on drivers of LULC change. Fill the knowledge gap by recommending priorities in LULC change to a developing country at a regional scale.

1.9. Structure of the research

This work consists of five chapters, where chapter one will be the general introduction, which comprise a brief detail of all above-mentioned points from the background to the research s that researchers will use in the study. This chapter comprises the introduction of the study, background of the study, problem statement, purpose of the study, the objectives of the study, research questions, scope of the study, significance of the study and the organisation of the study. The second chapter will be the literature review, which will be about the general understanding of the reviews of other researchers with the related studies. The third chapter will be the research methodology and it will focus on the methods and materials which will be used to achieve the objectives of the study. The fourth chapter will be the results and discussions and it will be the most important one because it will show the presentation of the results acquired. The fifth one, which will be the last chapter, will cover the conclusion and recommendations with respect to the predefined objectives.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

This Chapter provides a literature review of LULC change modeling. The first section of the literature review explains the concepts land, land use, and land cover. LULC change and factors which influence or drive LULC change have been reviewed from both a local and international perspective. After that, a summary of the most popular land-use model classification techniques has been provided based on published literature. The last section of the literature review presents the current agricultural status of Rwanda.

2.2 Land Use and Land Cover

2.2.1 Land

"An area of the earth's surface, the characteristics of which embrace all that are reasonably stable, or predictably cyclic, the attributes of the biosphere vertically above and below this area, including those of the atmosphere, the soil and underlying geology, the hydrology, the plant and animal populations, and the outcomes of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by humans," is how the Food and Agriculture Organization (FAO) defines land. Rossiter (1996). "The terrestrial bio-productive system that comprises soil, vegetation, other biotas, and the ecological and hydrological processes that operate within the system" is how the United Nations Convention to Combat Desertification defines land. Haber (1981).

2.2.2 Land Use

The terms land use and land cover are often used interchangeably, though they have different meanings. Land use is the purpose for which land is used, whereas land cover refers to the physical characteristics of the surface of the land. A formal description by FAO states that land use is “the arrangements, activities, and inputs people undertake in a certain land cover type to produce, change or maintain it" (FAO and UNEP, 1999).

Chapter 1 of the Spatial Planning and Land Use Management Act No 16 of 2013 (SPLUMA) defines land use as "the purpose for which land is or may be used lawfully in terms of a land use scheme, existing scheme or in terms of any other authorization, permit or consent issued by a competent authority, and includes and conditions related to such land use purpose." (Republic of South Africa, 2013; Ogunronbi, 2014).

This definition is however not entirely correct as people can take de facto control of land and use it for various purposes which may not align with any land use scheme or authorization (de Groot et al., 2010). The use of land is therefore uncertain, does not end at political boundaries and can be both legal and illegal (AIC, 2009). Land-use systems exist when different land uses are systematically linked through temporal interactions, e.g. crop rotation or spatial relations and are linked with land ownership (Angeles, 2005). Land-use change is the result and cause of diverse interactions between society and environment that lead to global change and rural development (Verburg et al., 2010).

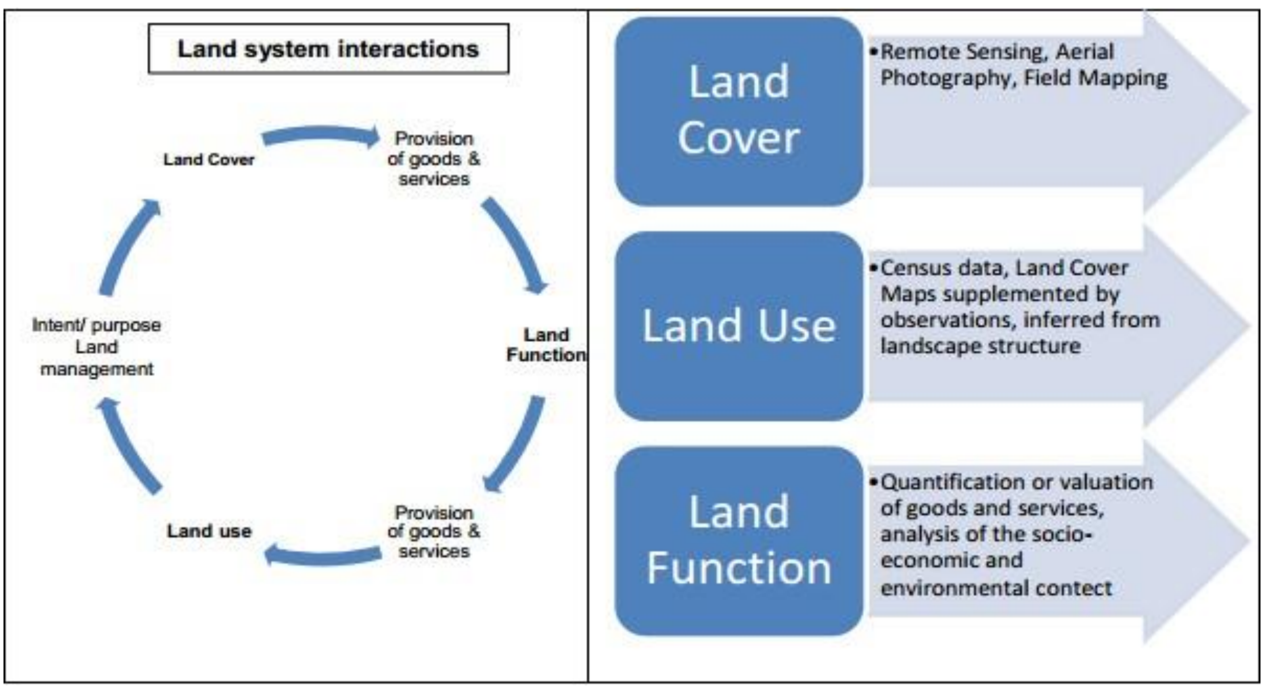


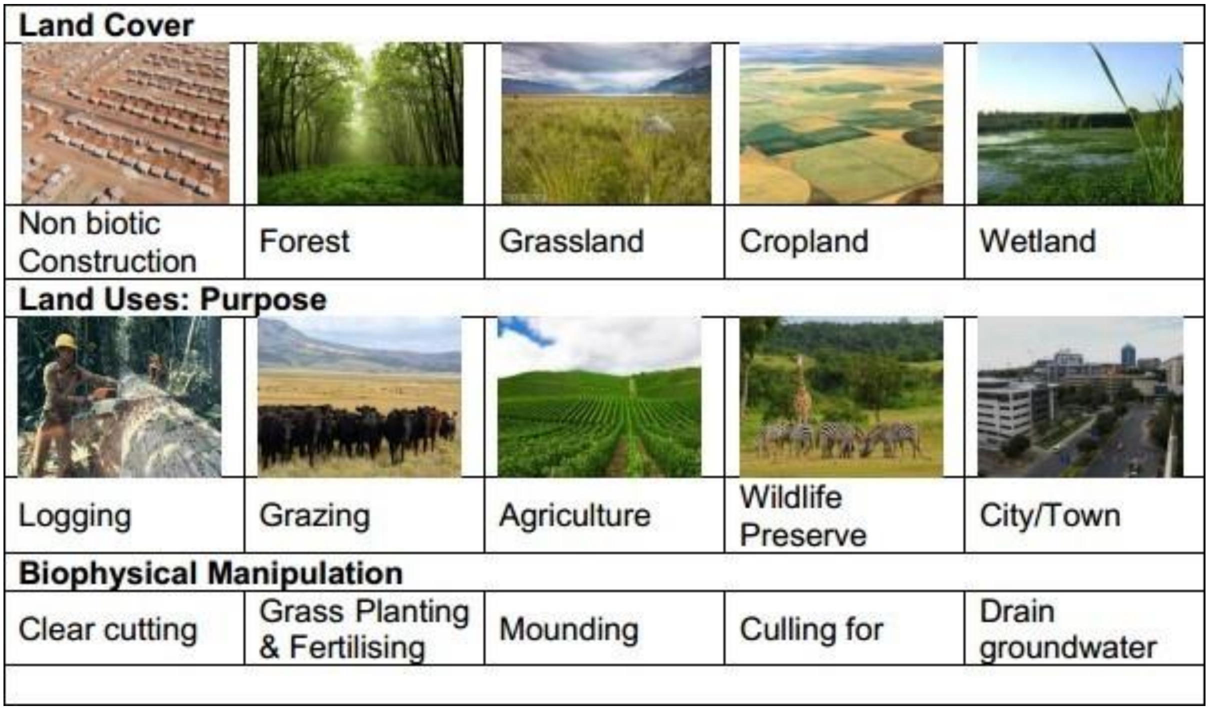
Figure 1**: Land Use, Land Cover and land Function interactions with their data collection methods (Source: Verburg et al., 2010)**

2.2.3 Land Cover

Land cover is a fundamental variable that impacts on and links many parts of the human and physical environments (Chase et al., 2000). Land cover change is therefore regarded as the single most crucial variable of global change affecting ecological systems with an impact on the environment that is at least as large as that associated with climate change (Niraula et al., 2010). Drought vulnerability drives land cover changes in the rift valley of East Africa (Biazin and Sterk, 2013) and growing scientific evidence proves that changes in anthropogenic land cover (ALC) produces a significant impact on regional climate (Deo et al., 2009). It is well established that land cover change has significant effects on basic processes including biogeochemical cycling and thereby on global warming (Feddema et al., 2005), the erosion of soils and thereby on sustainable land use and for at least the next 100 years is likely to be the most significant variable impacting on biodiversity (Cebecauer and Hofierka, 2008; Mohammad and Adam, 2010; Verburg, 2006).

According to (Turner et al., 2009), "Land cover is the biophysical state of the earth's surface and immediate subsurface." Land cover, therefore, includes quantity and types of all features over the earth such as vegetation, water, soil, artificial surfaces, etc. The difference between land use and land cover is demonstrated by (Turner et al., 2009) as illustrated in Table 2-1. (Turner et al., 2009) further add that land use involves the intent or purpose for which land is utilized. A different aspect, "biophysical manipulation" is also described as the manner which humans treat land to achieve intent, e.g. the planting of grass for pasture.

Figure 2**: Land cover and Land Use types**



Source: (Turner et al., 2009)

Land use and land cover are linked; however, it should be noted that a single land cover can support multiple land uses and vice versa. For instance, a land cover, e.g. grassland can support many land uses such as grazing and recreation and a single land use may also take place on various land covers. Land cover can be determined by analyzing remotely sensed images such as satellite images or aerial photos whilst land use and land-use change will require additional socio-economic data and methods to determine the activities occurring on the landscape (Pan et al., 2004).

(Thenkabail et al., 2007) agree with this and state that unlike land cover, land use is not directly observable though it can be inferred from activities such as grazing or structural landscape elements like logging roads. This study is conducted at a regional scale. The data will be used in analysis with a combination of data obtained from satellite imagery and socio-economic data. The term LULC will therefore be used to refer to land use and land cover in this study.

2.3. LULC Change and Drivers

2.3.1. International Review of Drivers of Land Use Change

According to Turner et al. (1994), LULC change refers to the conversion of one LULC into another or the intensification of the current LULC. How individual landowners, communities, corporations, and governments regulate land use and make decisions about it determines changes in Land Use and Land Cover (LULC). The interactions between environmental elements (such as terrain and climate) and socioeconomic factors (such as population) that change at different scales have an impact on these decisions (Turner et al., 2007).

This is further supported by (Barbier and Burgess, 2008), which further makes clear that environmental factors affect changes in land cover, which in turn affects decisions made by land managers, rather than directly affecting changes in land use. As a result, LULC change can be represented as a function of environmental and socioeconomic variables. These elements are frequently called "driving factors." The proximate and underlying driving reasons of LULC change are also classified as either direct adjustments made by persons at a local scale, such individual farms, or indirect changes made at a regional scale. (Turner and others, 2007).

While underlying causes are the result of intricate interactions between social, political, demographic, and environmental variables, proximate driving factors are typically the result of human activity like the development of infrastructure and agriculture (Lele and Joshi, 2008). The activities or variables that make up Figure 2-2's demonstration of agricultural development, wood extraction, and infrastructure expansion are the three main categories into which proximate causes can be divided, according to (Lele and Joshi, 2008).

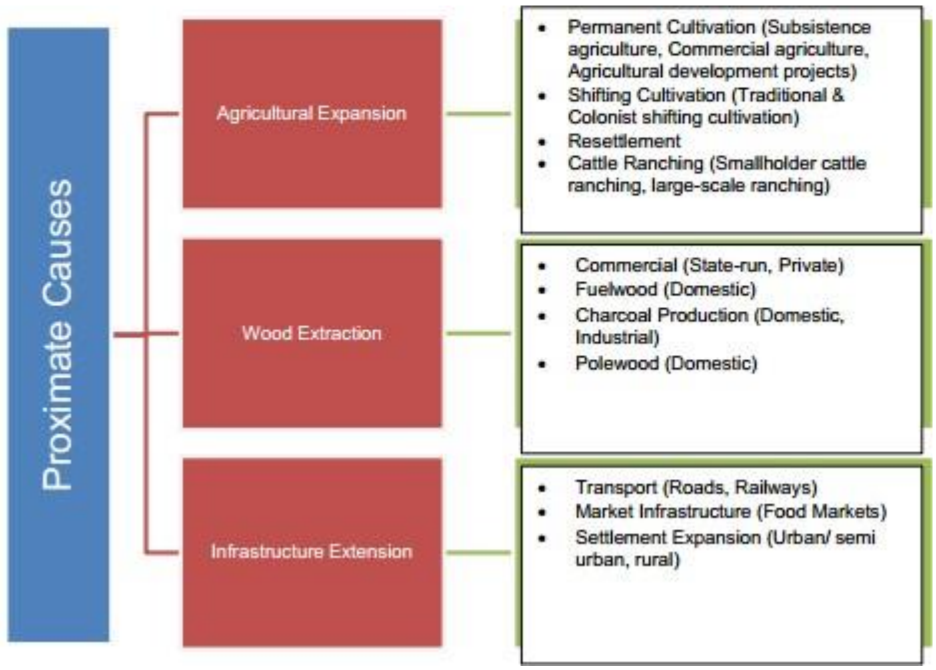


Figure 3**: Proximate causes of LULC change and their variables (Source: (Caldas et al., 2015)).**

(Caldas et al., 2015) describes underlying driving forces as socio-economic drivers, which comprise population change, infrastructure development, economic, market factors, institutional factors, technological and cultural or socio-political factors. The proximate causations are factors such as agricultural and cattle expansion. These components of underlying driving forces are further explained by (Lele and Joshi, 2008) and summarized in Figure 2-3 below.

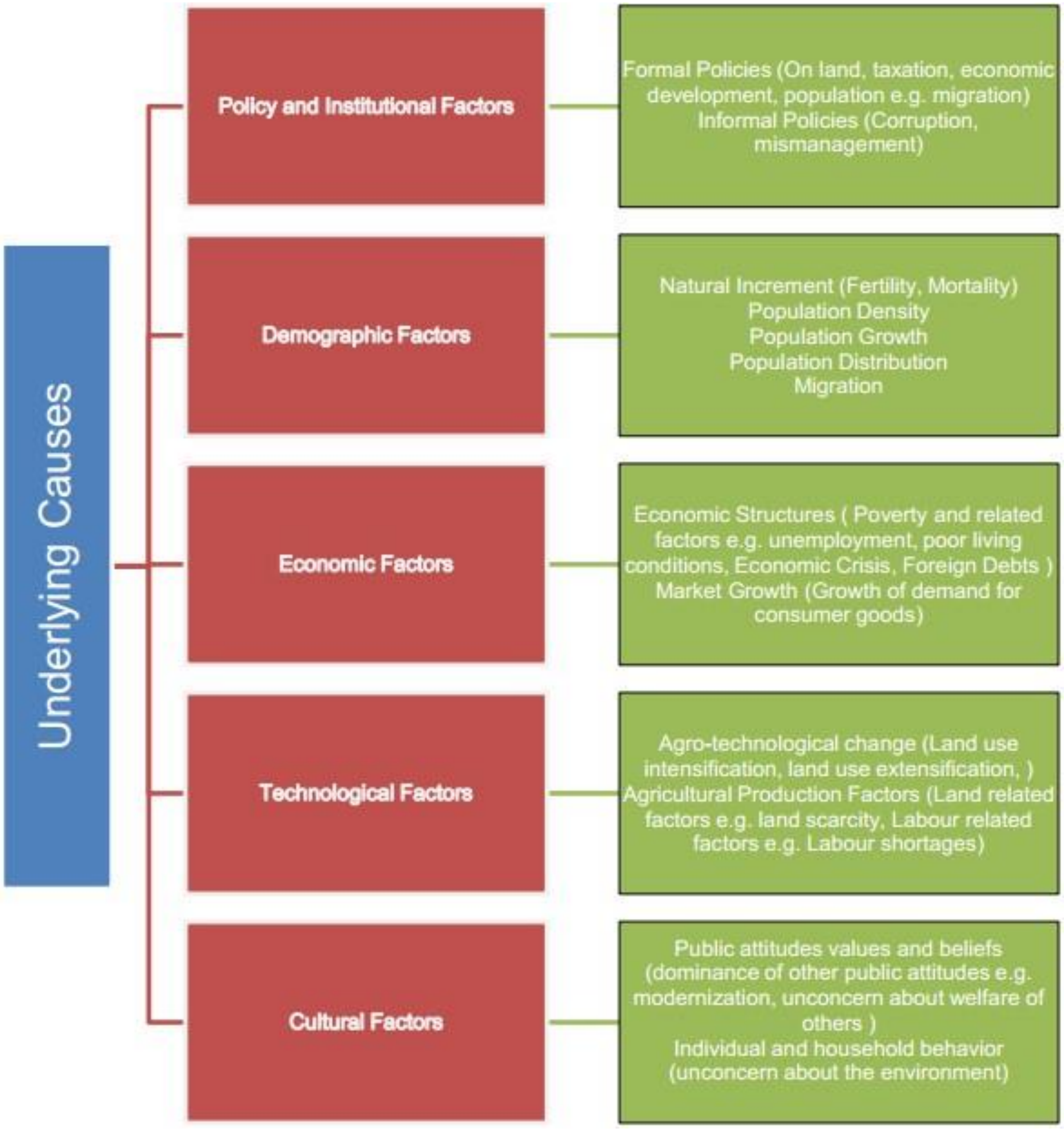


Figure 4**: Underlying causes of LULC change and their variables (Source: (Lele and Joshi, 2008)).**

2.3.2 Review of Drivers of LULC in Rwanda

This section of the literature review covers drivers of LULC change in Rwanda. Land-related problems in Rwanda are multiple and varied (GoR, 2004). The focus will be on underlying causes, which consist of political, demographic, economic, technological, cultural, and environmental variables. This is because unlike proximate factors, underlying factors operate at regional levels which coincide with the scale of this study.

2.3.2.1 Political factors

The LULC movement in Rwanda is mostly fueled by a number of laws and regulations. The communal ownership of land, where agriculture and cattle were complementary, was the hallmark of the pre-colonial Rwandan land tenure system. This approach aided in the development of social ties by stabilizing the economy and fostering peace. Clans were formed from the lineages that families belonged to. Every tribe had a leader. Clans were dispersed throughout the country, varying in number depending on the area. Thus, free land usage and the complementarity of the modes of production served as the foundation for land ownership arrangements.

Pre-colonial Rwanda's political structure was centered on controlling the economy, which was supported by three main pillars: cattle, land ownership for agriculture, and security to ensure prosperity. Significant changes in the nation's management brought about by Belgian colonization eventually led to the dismantling of the established system. Thus, this historic trio—which stood for a framework of social balances at the national level—was disassembled and changed into a centralized government. According to (GoR, 2004), the 1926 reform created chieftainships throughout the nation and did away with the practice of a chief having many land holdings around the nation, signifying his status as a top official. Nonetheless, national cohesiveness and unity have been aided by this kind of government. Rwandan society saw numerous disruptions as a result of the removal of these long-standing institutions in order to gain more control over the nation and secure the acceptance of colonial authority. But land management continued to incorporate elements of customary methods.

The written legislation found in Rwanda's "codes and laws" was also brought about by Belgian colonization, primarily to ensure the security of land tenure for immigrants and other foreigners looking to make land investments in Rwanda. The colonial government established the paysannat system, which was akin to the old "Gukeba" system of group homesteads, in response to the dense population and the necessity to colonize additional territories. This system, which gave each household two hectares to cultivate cash crops like cotton in Bugarama and coffee in Mayaga, was developed in areas with grazing land and other land reserves. This method encouraged the expansion of cultivated land to the disadvantage of livestock and was implemented following the elimination of the Ubuhake system and the dispersion of cattle in grazing areas (Ibikingi).

Thus, a new facet of national growth was brought about, emphasizing agriculture above all else and upending the long-standing equilibrium between livestock and agriculture. Conflicts arose as a result of this development, both actual and potential. There were genuine tensions at the time, despite the fact that there were no overt clashes between the local populace and the government in this system where agriculture predominated over livestock. As a result, a sizable portion of the cattle breeding community emigrated to the Democratic Republic of the Congo and Umutara, Uganda.

The land tenure system started to play a role in actual conflicts among the populace around 1959. It was at this time that the first wave of refugees ever went into exile, abandoning their homes and lands behind as a result of the political crisis that broke out.

2.3.2.2. Land situation after independence

Following independence, the government assigned the "communes" a crucial responsibility in land administration. The commune was given authority to safeguard rights pertaining to land registered under customary law by the "Loi Communale" of 23/1/63. On the other hand, Decree No. 09/76 regarding the purchase and sale of customary land rights or land use rights effectively rendered the provisions of this law null and valid. The 1970s and 1980s were marked by a large-scale migration from the already densely populated regions of Gikongoro, Ruhengeri, Gisenyi, and Kibuye to the semi-arid savannas of the East (Umutara, Kibungo, and Bugesera) in search of unclaimed land. At the beginning of the 1960s, the government relied on abolishing the system of "Ibikingi" to place them under the authority of the "communes" and on recovering the land abandoned by the 1959 refugees to acquire new agricultural land. Around this time, the government made an effort to convert the current system of human settlement into one of the grouped homesteads, or "paysannat." The goal was to rationalize the usage and occupation of land, which was become increasingly limited (Oshodi, 2014).

Decree No. 09/76 of 04/03/76, which dealt with the purchase and sale of customary land rights, also known as the right of soil usage, allowed anyone to buy and sell customary land in 1976 as long as they applied to the appropriate authorities. They have to keep at least two hectares of land. Additionally, the buyer had to provide evidence for his lack of land holdings totaling at least two hectares. Since then, the government has only acknowledged ownership rights based on land registration, making it the dominant landowner.

There were no more newly acquired lands by the start of the 1980s, and issues like decreased soil fertility and smaller arable land sizes, family disputes resulting from land ownership, food shortages, etc. started to surface. According to the agricultural census conducted at the time, the average area of a family's crop allotment decreased from 2 ha in 1960 to 1.2 ha in 1984 (GoR, 2004).

Since the early 1990s, the nation has been stuck in a land-related situation. A number of issues surfaced, such as inadequate agricultural output, increased population strain on natural resources, a growth in the number of landless peasants, and conflicts arising from the interaction of natural reserves, agriculture, and cattle. The government reinforced its position as the owner of large areas of property through agricultural projects, especially those related to forestry and grazing land. The State and private citizens now depend heavily on reforestation while accumulating land. Even on arable ground and in marshlands, forests stretched. Thus, replanting evolved into a straightforward method of acquiring long-term land. Nevertheless, issues including excessive plot parceling out, deforestation, and the slow degradation of the soil continued despite efforts (MININFRA, 2009; MOH, 2009; Karadaş, 2011).

2.3.2.3 Demographic factors

Numerous academic works have demonstrated that factors such as household size, migration, and urbanization—rather than sheer population growth—are what drive pressure on land usage in relation to population composition and distribution (Gennaio et al., 2009; Smith, 2013; Ecology, 2014). The next sections provide an explanation of these elements, along with their ramifications (especially with regard to housing) and how they interact with government policy.

• **Migration and Urbanization in Rwanda**

Migration is a concern in most developing countries. Even though the reasons for migrating vary from country to country, the most common for internal migration in Rwanda is the problem of food security and security issue for international migration. A combination of political, social, economic, and demographic factors drives internal and international migration in Rwanda.

International migration involves movement across national boundaries, whereas internal migration involves movements within the same country.

➢ **Internal Migration**

Internal migration in Rwanda is mostly characterized by temporary circular migration and permanent migration to urban areas (Lawrence and Uwimbabazi, 2011). Circular migration involves movement to places of work, mostly business or education, while permanent residence remains in the rural or peri-urban setting in settlements and some parts of the cities (Urbanization Rwanda, 2017). In rural areas, a large percentage of employment relies on agriculture. However, poverty, unproductive land, and the need to survive often lead to the breakup of rural communities, impelling migration to urban locations. In Rwanda, migration to urban cities is extensive and this can be attributed to three main factors.

The first is limited land and high level of poverty in Rwandan's rural regions, the second is the pattern of migration to urban areas that is not adequately managed and the third is that due to the scarcity of land, the government of Rwanda is promoting grouped settlements namely "imidugudu" so that people can use their small piece of land for strategic farming to combat food insecurity affecting most of rural areas in Rwanda. These grouped habitats intend to improve aspects of basic service delivery such as water, electricity, schools, and hospitals and to afford security. Despite this positive-sounding strategy, people fail to cope with the new living conditions found in grouped settlements and then choose to move once again towards major cities, especially to the capital, Kigali (Lawrence and Uwimbabazi, 2011).

Table 1**: Distribution of the resident population by lifetime migration status, sex and area of residence**

Area of residence and Sex	**Lifetime-migration status**			**Percentage of Migrants**
	Number of Migrants	**Number of non-migrants**	**Not stated**	
Rwanda				

Male	1,013,922	4,045,357	5,589	20.00%
Female	1,079,727	4,365,517	5,861	19.80%
Total	2,093,649	8,410,874	11,450	19.90%
Urban				
Male	438,317	451,625	1,864	49.10%
Female	387,868	456,144	1,866	45.90%
Total	826,185	907,769	3,730	47.50%
Area of residence and Sex	**Lifetime-migration status**			**Percentage of Migrants**
	Number of Migrants	**Number of non-migrants**	**Not stated**	
Rural				
Male	575,605	3,593,732	3,725	13.80%
Female	691,859	3,593,732	3,995	15.00%
Total	1,267,464	7,503,105	7,720	14.40%

Source: (NISR, 2014a)

The distribution of lifetime migrants by province and area of residence shows that only two Provinces (Kigali City and the Eastern Province) exhibit a relatively higher percentage of migrants than the national average (about 20%). In Kigali City about 54% of the resident population are lifetime migrants, while lifetime migrants represent about 34% of the resident population in the Eastern Province (Table 2). Table 2 also shows that more males (about 326,000) than females (285,000) moved to Kigali City and slightly fewer men (about 416,000) than women (453,000) moved to the Eastern Province.

For Kigali City, this may be explained by the supply of employment opportunities in various sectors: this pushes people to leave their district of birth and migrate to the capital. For the Eastern Province, this migration may be explained through the recent availability of land or as the result of family or employment reasons. According to the Integrated Household Living Conditions Surveys (EICV2 and EICV3), the main reasons to migrate to the Eastern Province were family, employment and a lack of land in the 'sending' province, accounting for 71% of migrants to the east in EICV2 and 86% in EICV3 (NISR 2012, Main Indicators Report EICV3). Except the Eastern Province, where the percentage of migrants in rural and urban areas is similar (about 46% in urban and about 33% in rural areas), the difference between urban and rural areas are substantial, reinforcing the idea that migration is more an urban phenomenon than a rural one. (Table 2-3).

Table 2**: Number and Percentage of the population which has experienced a lifetime migration by sex, province, and area of residence (Source: (NISR, 2014a))**

Province and Area of Residence	**Male**		**Female**		**Both Sexes**	
	Number of Migrants	**% of Migrants**	**Number of Migrants**	**% of Migrants**	**Number of Migrants**	**% of Migrants**
Rwanda						
Urban	438,317	49.1%	387,868	45.9%	826,185	47.5%
Rural	575,605	13.8%	691,859	15.0%	1,267,464	14.4%
Total	1,013,922	20.0%	1,079,727	19.8%	2,093,649	19.9%
Kigali City						
Urban	291,572	64.6%	249,446	61.2%	541,018	63.0%
Rural	34,517	25.7%	35,378	25.5%	69,895	25.6%
Total	326,089	55.6%	284,824	52.1%	610,913	53.9%

South						
Urban	42,122	35.3%	34,906	31.6%	77,028	33.5%
Rural	95,574	8.6%	132,086	10.6%	227,660	9.6%
Total	137,696	11.2%	166,992	12.3%	304,688	11.8%
West						
Urban	42,675	28.5%	40,517	26.7%	83,192	27.6%
Rural	49,923	4.9%	69,043	6.0%	118,966	5.5%
Total	92,598	7.9%	109,560	8.4%	202,158	8.2%
North						
Urban	18,541	24.0%	21,014	25.2%	39,555	24.6%
Rural	22,928	3.1%	44,018	5.3%	66,946	4.3%
Total	41,469	5.1%	65,032	7.2%	106,501	6.2%
East						
Urban	43,407	46.2%	41,985	45.4%	85,392	45.8%
Rural	372,663	32.0%	411,334	33.0%	783,997	32.5%
Total	416,070	33.1%	453,319	33.9%	869,389	33.5%

Figure 5, presenting the distribution of the lifetime migrant population by the province of birth and the current province of residence, offers an idea of the importance of in-migration related to the size of the lifetime migrant population at the current province of residence. It is important to remember that lifetime migration is measured across district boundaries, so some lifetime migrants might have migrated to a different district from their place of birth, but they still live in the same province. This is emphasized by the figure above.

First, it shows that the lowest lifetime migrants currently still living in the province in which they were born found in Kigali City, while the highest (about 58%) was found in the Southern Province. This means that Kigali City is the province with the highest percentage of lifetime in-migrants that was born in a different province or abroad (about 89%), followed by the Eastern Province (about 82%). Secondly, most of the lifetime migrants in Kigali City come from the Southern Province (about 31%), the Western Province (about 18%) and from abroad (about 18%), whereas most of the lifetime migrants in the Eastern Province come from the Northern Province (about 31%), the Southern Province (about 16%) and from abroad (about 16%).

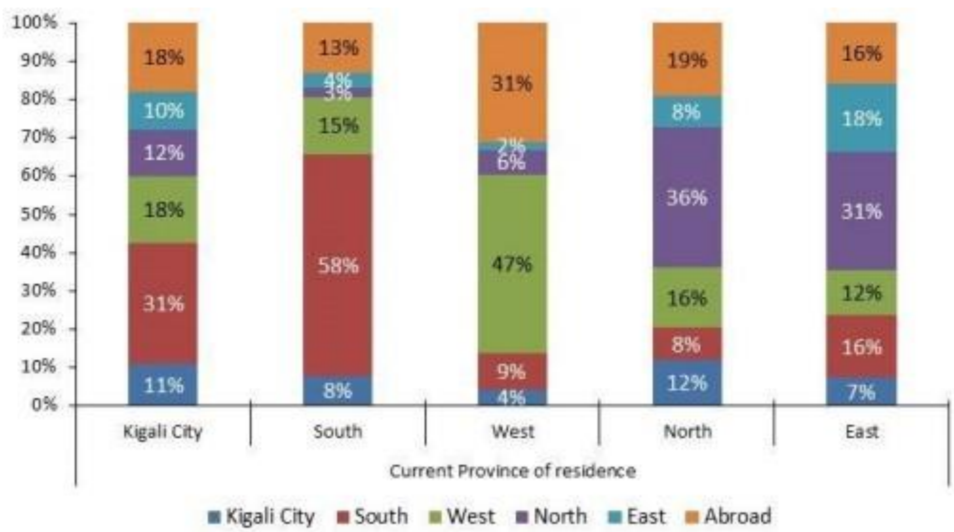


Figure 5**: Distribution of the lifetime migrant population by the province of birth and current province of residence (%)**

Figure 6, presenting the distribution of the lifetime migrant population by the province of current residence and place of birth, provides an overview of the out-migration movements from the place of birth. It shows that most of the out-migrants from the Northern Province have moved to the Eastern Province (about 67%) and Kigali City (about 18%), while those from the Western Province have mainly moved to Kigali City (about 30%) and the Eastern Province (about 28%).

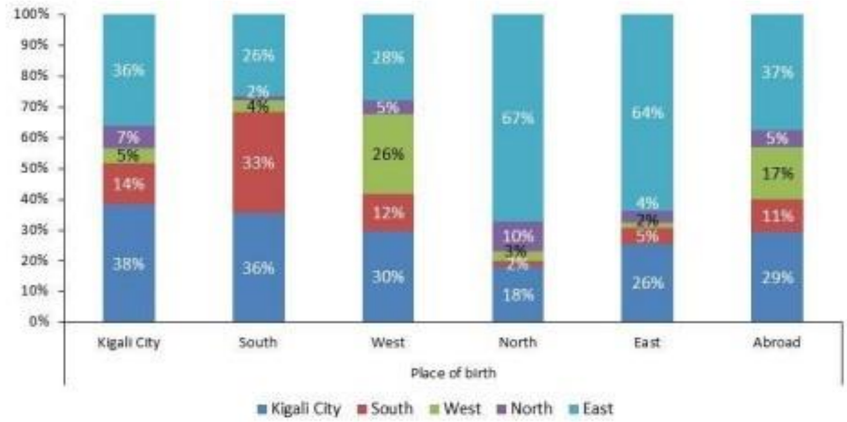


Figure 6**: Distribution of the lifetime migrant population by the current province of residence and place of birth (%)**

Figure 7 also shows the main destinations of lifetime migrants that were born abroad. They are located mostly in the Eastern Province (about 37%), Kigali City (about 29%) and the Western Province (about 17%).

➢ **International Migration**

International migration into Rwanda is currently triggered by poverty, deteriorating economic conditions, and political instability in neighboring countries (Boswell, 2002; Since & ICPD, 2004). (NISR, 2014a) defines international lifetime immigrant as a resident individual whose place of birth is abroad. In Table 3, the distribution of the international lifetime immigrant population by sex and area of residence shows that foreign-born residents are a rather small group, representing about 4% of the resident population. The percentage of foreign-born residents is about five times higher in urban areas (about 10%) than in rural areas (about 2%).

According to a report by National Institute of Statistics of Rwanda (NISR), 48% of recent international immigrants living in Kigali City were previously living in Burundi, and 37% were previously in the DRC. 88% of international immigrants living in the Southern Province were previously living in the DRC. The high percentage of Congolese now residing in the Southern Province is partly the result of the Congolese refugees there in the Kigeme refugee camp, estimated at around 19,500 in 2018 (Since & ICPD, 2004; UNHCR, 2018), 46% of recent international migrants in the Western Province had their previous residence in the DRC and 35% in Uganda. Those living in the Northern Province were previously residing in various neighboring countries:

32% in Uganda, 31% in Burundi and 22% in Tanzania (National Institute for Statistics (NISR), 2015).

Table 3**: Distribution (number and percentage) of the resident population by international lifetime migration status, sex and area of residence**

Area of residence and Sex	**International Life Migration Status (Count)**			**Percentage of Foreign Born Migrants**
	Number of Foreign-Born Migrants	**Number of non-migrants**	**Not stated**	
Rwanda				
Male	188,841	4,870,438	5,589	3.70%
Female	181,390	5,263,854	5,861	3.30%
Total	370,231	10,134,292	11,450	3.50%
Urban				
Male	95,770	794,172	1,864	10.70%
Female	84,459	759,553	1,866	10.00%
Total	180,229	1,553,725	3,730	10.40%
Rural				
Male	93,071	4,076,266	3,725	2.20%
Female	96,931	4,504,301	3,995	2.10%
Total	190,002	8,580,567	7,720	2.20%

Source: (NISR, 2014a)

Figure 7 with percentages, illustrates that the percentage of foreign-born females is slightly high in all provinces except in Kigali City, where 55% are males, and in the Eastern Province, where the percentage of females is equal to the percentage of males.

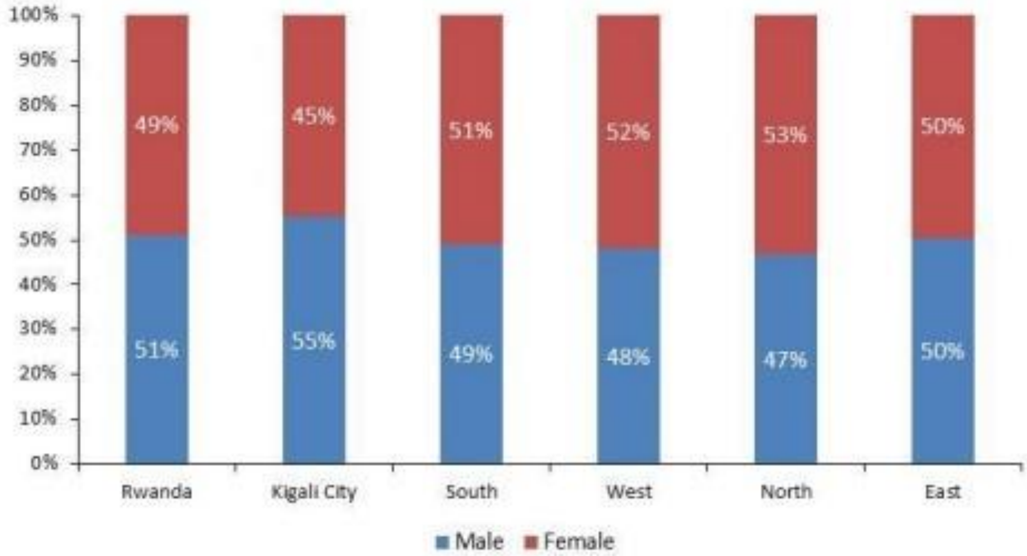


Figure 7**: Distribution of international lifetime migration status by sex and province (%) (Source:** (NISR, 2014a)**).**

• Effects of Population Growth and urbanization

The principal economic activity in rural areas of Rwanda is Agriculture. The size of plots for households is insufficient considering the population density that is high (IPAR, 2009; Report, 2014). Population growth exerts positive pressure on urbanization growth while the impacts of population density in agricultural areas is negative. Productive areas are covering increasing pressure on land with increasing runoff and in turn enhance water resources degradation. An increase in population and urbanization leads to pressure on these natural resources resulting in serious issues such as landscape change (Antrop, 2004), poverty, under-serviced informal housing and land degradation (Dao, 2002).

Increased effects of urbanization are evident in Rwanda's housing and transport sectors where the demand for housing in urban areas is continuously increasing yet there is no affordable land close to places of business and work, thus resulting in shacks in peri-urban areas and expensive transport costs (Poumanyvong et al., 2012).

2.3.2.4 Economic and Technological factors

Economic factors can be in the form of taxes, investments, access to capital, markets, cost of production and transportation, technology, and subsidies (Barbier, 1997). Land managers are stimulated by these economic factors. Besides, they are also motivated by profitability and feasibility of particular land-use. Economic factors, combined with institutional and technological factors play a significant role in land-use change. For example, giving farmers access to capital and markets and agricultural technology can encourage agriculture expansion and conversion of land (Hussein, 2001).

• **Land Markets**

"Land Markets are mechanisms by which rights in land and housing, either separately or together, are voluntarily traded through transactions such as sales and leases. These transactions may take place on the formal land market, or may happen through informal channels such as informal land developers". In a land market, a developer searches and scrambles for land. When demand for a particular piece of land increases, its value also increases, leading to demand and supply where demand is triggered by increase in population, household development projects, and availability and access to credit funds (Wallace and Williamson, 2006).

Heavy competition for land exists between the private and public sectors, where the main objective of the private sector is to accumulate as much profit from the land as they can generate, but is reluctant to participate in the delivery of affordable housing projects. Therefore, if land is accessed by the private sector, they will allocate it mostly to office parks, shopping malls, high income generating development projects, etc. However, for the government side the land is used for building housing settlements to meet what the population can afford for rent. In grouped settlements, the government provides facilities similar to those offered in cities (Habiyaremye et al., 2011).

2.3.2.5 Environmental Factors

Environmental factors are biophysical factors which "define the natural capacity or predisposing environmental conditions for land-use change, with the set of abiotic and biotic factors – climate, soils, lithology, topography, relief, hydrology and vegetation" (Linard et al., 2007; Wohlfahrt et al., 2008).

The interactions between environmental variables and human activities influence land-use change, e.g. relief determines the extent to which machinery can be used and the rates of erosion. Steep slopes are difficult for operating modern farm machinery and are subject to erosion thus limiting exploitation. Changes in land-use such as agriculture are influenced by environmental factors, e.g. climate (rainfall, wind, temperature) and soil conditions (Matson et al., 1997; Buck et al., 2004; Dale et al., 2011).

• **Soil**

Fischer et al. (2007) identified constraints for physical and chemical properties of soil which are essential for land exploitation as terrain-slope, soil depth, soil fertility, soil chemical, soil texture, soil drainage. Soil loss, compaction, poor drainage, salinization, and acidity are classified as soil degradation, which is common in Rwanda and contributes to low productivity of the soil (Kagabo et al., 2013). High population density and steep slopes make it difficult for the peasant farmers to control erosion. Fragmentation and small farm sizes are characterized by overstocking, soil erosion, excessive wood harvesting, and high population and are generally perceived as degraded (Clay and Lewis, 1990). Land degradation is one of Rwanda's critical environmental issues which is linked to food security, urbanization and climate change (Byiringiro, 2002; Hategekimana and Twarabamenya, 2007).

• **Water availability**

The availability of water resources influences land uses such as agriculture and activities associated with it (Kannan et al., 2010; Munyaneza et al., 2014). Agriculture and crop irrigation are the dominant users of water in Rwanda but still face challenges of water scarcity, and uneven and unreliable rainfall with abundant rainfall in the Northern Province whether in the East rainfall is insufficient. Just 11% of the land in the nation is permanent cropland, despite the fact that 79% of the area is categorized as agricultural. The remaining agricultural lands are covered in marshlands, woodlands, and marginal hillsides where regular and permanent crop cultivation is not feasible. A total of 2,294,380 hectares of arable land are available for cultivation; of these, 1,735,025 ha are used for food and cash crops, with the remaining portion being pastures and bushes (Muhinda and Dusengemungu, 2011). However, these land uses face competition from other uses, such as residential and industrial developments, mining, and other factors like water availability and climate change.

All of the aforementioned elements necessitate an understanding of how governments and individuals decide how to utilize land, as well as how different factors interact in particular situations to affect changes in land use. These variables will be investigated more in the Lake Cyohoha watershed and confirmed by land use planning specialists. The theory of Rwanda's current agricultural situation will be the main topic of the literature review's next section.

2.4 Agriculture status in Rwanda

2.4.1 Introduction

Most of Rwanda's economy is based on agriculture (Hoyweghen, 1999). Rwanda is expected to have 12 million people, of which more than 80% are dependent on farming (NISR, 2016). The nation's whole land area is 24,700 square kilometers. Just 11% of the land in the nation is permanent cropland, despite the fact that 79% of the area is categorized as agricultural. The residual agricultural areas consist of forests, marshlands, and marginal hillsides where regular and permanent crop production is not feasible.

The majority of people—more than 80%—live in rural areas and depend on small-scale farming. At 407 people per square kilometer on average, Rwanda is the most densely inhabited country on the continent. As a result, Rwanda has a very uneven and fragmented land distribution. In Rwanda, land is the most precious, productive, and contentious resource. Thus, proper land management is essential. Nonetheless, until the 1990s, the majority of the laws pertaining to land management and administration in the nation had been created by colonialists and were still in effect today. According to (Daley et al., 2010), Rwanda is implementing a number of reforms and policies, with the Land Use Consolidation policy being essential to the country's agricultural transformation (Musahara and Huggins, 2004; Muhinda & Dusengemungu, 2011).

The overarching strategies of economic development and poverty reduction in Rwanda that envisioned social transformation through agriculture require shifting from such subsistence farming to commercially oriented agriculture. It has been followed by National Strategy for Transformation that will accelerate inclusive economic growth and development founded on the private sector, knowledge and natural resources (MINECOFIN, 2017). In Rwanda, the growing demographic pressure on land and continued fragmentation of households' plots by inheritance forced the land-use patterns to be inevitably re-organized. The volume of food crop production is function of physical land area and the productivity of land under cultivation.

Crop productivity, often measured as the ratio of farm outputs to inputs, reflects the efficiency of usage of inputs. However, the efficiency of the inputs depends on the size of the farmland (Byiringiro, 2002; Cantore, 2011; Cioffo et al., 2016). Land fragmentation thus affects productivity and competitiveness of smallholder farms (Bizimana et al., 2004). Furthermore, the inherent difficulties in mechanizing farm chores in small farms also impede public and private investments.

2.4.2 Agriculture Intensification

Agriculture is a significant component of Rwanda's national economy (MFEP, 2000). The favorable climatic conditions and the generally fertile soils allow cultivation of a wide range of crops in Rwanda. Major food crops include maize, rice, banana (cooking, beer, and fruit), Irish potato, sweet potato, cassava, sorghum, and beans. Vegetables such as onions, cabbages, dodo, gourds, and eggplants are also widely grown. Cash crops such as coffee, tea, and sugarcane are grown on commercial scales for exports and domestic consumption in Rwanda. Cultivation of food crops, on the other hand, has long been predominantly grown by smallholder farmers for subsistence living. As a result, the on-farm productivity levels have been deficient in Rwanda (Kathiresan, 2011).

The low productivity is attributed to the use of low inputs. As a consequence, many smallholder farmers produce the quantity which is neither enough for their consumption nor the market and therefore have no income with which they may invest in buying inputs. Increasing agricultural productivity and food security in Rwanda therefore requires replication of such adoption of modern inputs by the smallholder farmers. Setting this as the goal, the Ministry of Agriculture and Animal Resources (MINAGRI) developed Crop Intensification Program (CIP) in 2008 (Nahayo et al., 2017). Since most of the inputs have to be imported, the cost of transportation to remote areas combined with the inherent reduced demand for inputs keep the prices of the inputs high. The government with the help of development partners overcame this hurdle through bulk procurement of improved seeds and fertilizers from neighboring countries and distributed the inputs to farmers through a network of public and private partnerships (Cantore, 2011; Nahayo et al., 2017). The following Figure 8 highlights the impacts that CIP has had during the first three years of its implementation.

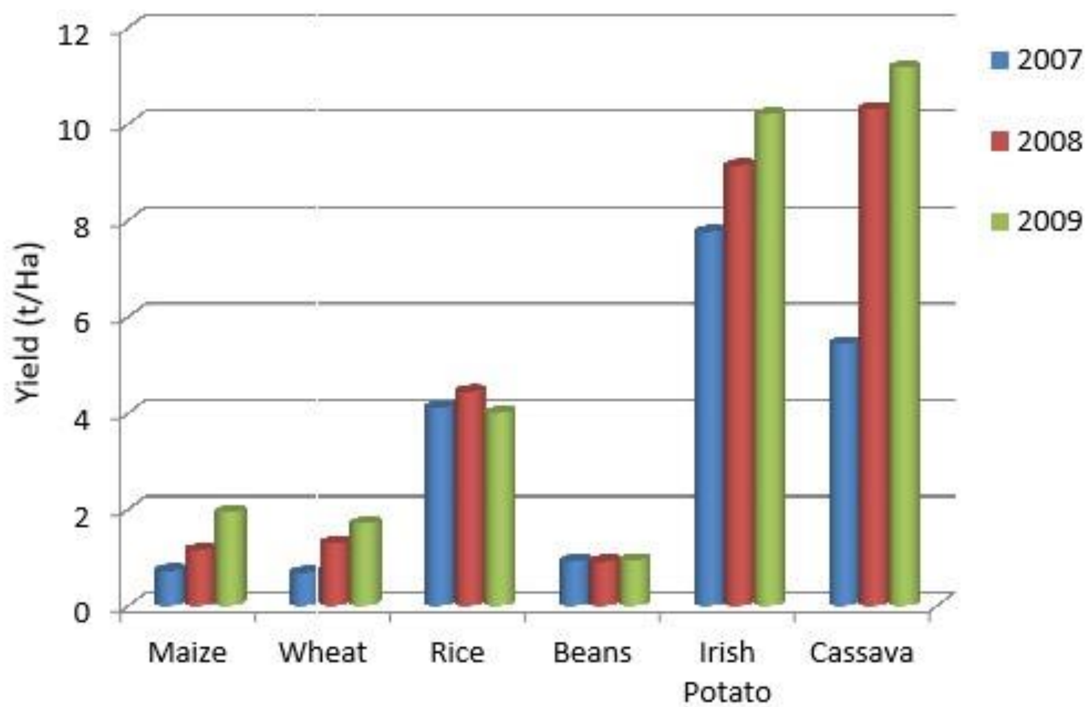


Figure 8**: Changes in on-farm productivity of selected crops in response to the use of distributed inputs (Source:** (Rudel et al., 2009)**).**

From 2007 when CIP was implemented, the program has taken several approaches to increase the production and benefit farmers. During the first three years, the production of the beans has doubled, and the production of rice and Irish potatoes has increased by 3O%. The figure 2-7 above shows that the total production improved mainly because of the increase in productivity per unit land area. Such outputs have transformed Rwanda from a list of food-insecure countries to a country with improved food security. The CIP has provided the much-needed foundation for a positive change in Rwanda's agriculture development. The program has also revealed the massive potential that exists in the country in increasing the smallholder agricultural productivity which is the last objective of this research in the catchment of Lake Cyohoha. It has also testified that the cost of achieving food security is fiscally manageable and responsible. It demonstrates that landuse patterns can define the growth in productivity and development of the agriculture sector and shows that a program of national scale is feasible (Thomas and Christopher, 2005).

2.4.3 Land Use Consolidation

Following the president's visit to Malawi in 2004, when the government realized the true benefits of consolidated lands, the Land Use Consolidation Policy was announced. The Rwandan government's Ministry of Agriculture originally introduced the LUC policy in 2008 as a component of the Crop Intensification Program (CIP). The same Ministry launched the CIP in September 2007 with the goals of boosting high-potential food crop productivity and enhancing Rwanda's food security and self-sufficiency.

Land Use Consolidation is the main pillar of this program's implementation. Other components include the delivery of inputs (seeds and fertilizers), post-harvest technologies (such as driers and storage facilities), and proximity consulting services to farmers. In order to increase the amount of land under production, avoid relying solely on rain-fed farming, and utilize farm power in the context of market-oriented agriculture, the program is also supported by additional initiatives including land-husbandry, irrigation, and mechanization infrastructure development (Nilsson, 2018).

The LUC strategy is consistent with initiatives taken by the Rwandan government to reduce poverty and hunger. It is related to both CIP and the "Villagization" of the current resettlement initiative, "Imidugudu," which commenced in early 2004. As a result, several parties are involved in its implementation process, including the private sector, NGOs, Ministries, and Civil Society Organizations (Rubanje, 2016). Figure 9 illustrates LUC's participative approach during the implementation of CIP.

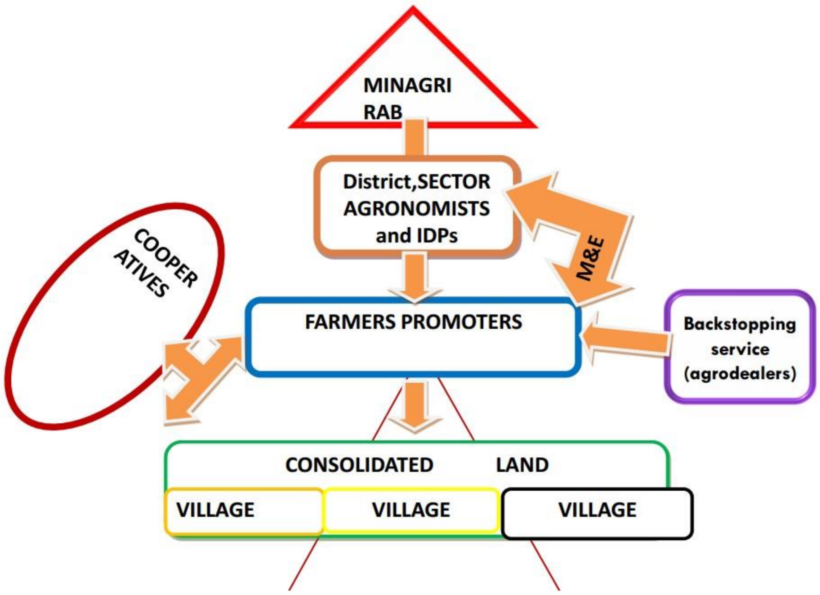


Figure 9**: Farm LUC Implementation Process**

2.4.3.1 Priority food crops under LUC

Under the land use consolidation program, eight priority crops—Irish potatoes, cassava, beans, maize, wheat, rice, bananas, and soybeans—have been chosen for promotion. Based on competitive advantage, crop suitability in a particular agro-ecological zone, and crop contribution to overall food security, the rotation system is implemented. According to a recent cross-border trade study, crops like maize, beans, cassava, and Irish potatoes have demonstrated a positive trade balance and a competitive edge.

The Government of Rwanda (GOR) has made the decision to build food storage facilities and driers where land has been consolidated in order to address post-harvest and marketing issues (Isaacs, Snapp, Chung, & Waldman, 2016). Farmers that use their lands more collectively are able to take advantage of the many services provided by the CIP, including: (i) more effective input delivery (better seeds and fertilizers), (ii) proximity extension services, (iii) post-harvest handling and storage facilities, (iv) irrigation and mechanization by public and private stakeholders, and (v) concentrated markets for inputs and outputs.

The entire area under land use consolidation has grown eighteen times since it was first implemented in 2008, rising from 28,016 hectares to 602,000 hectares in 2012. The graph below shows the growth in LUC under priority crops over time, with the goal of fully consolidated land covering over 700,000 hectares by 2017 (Muhinda & Dusengemungu, 2011).

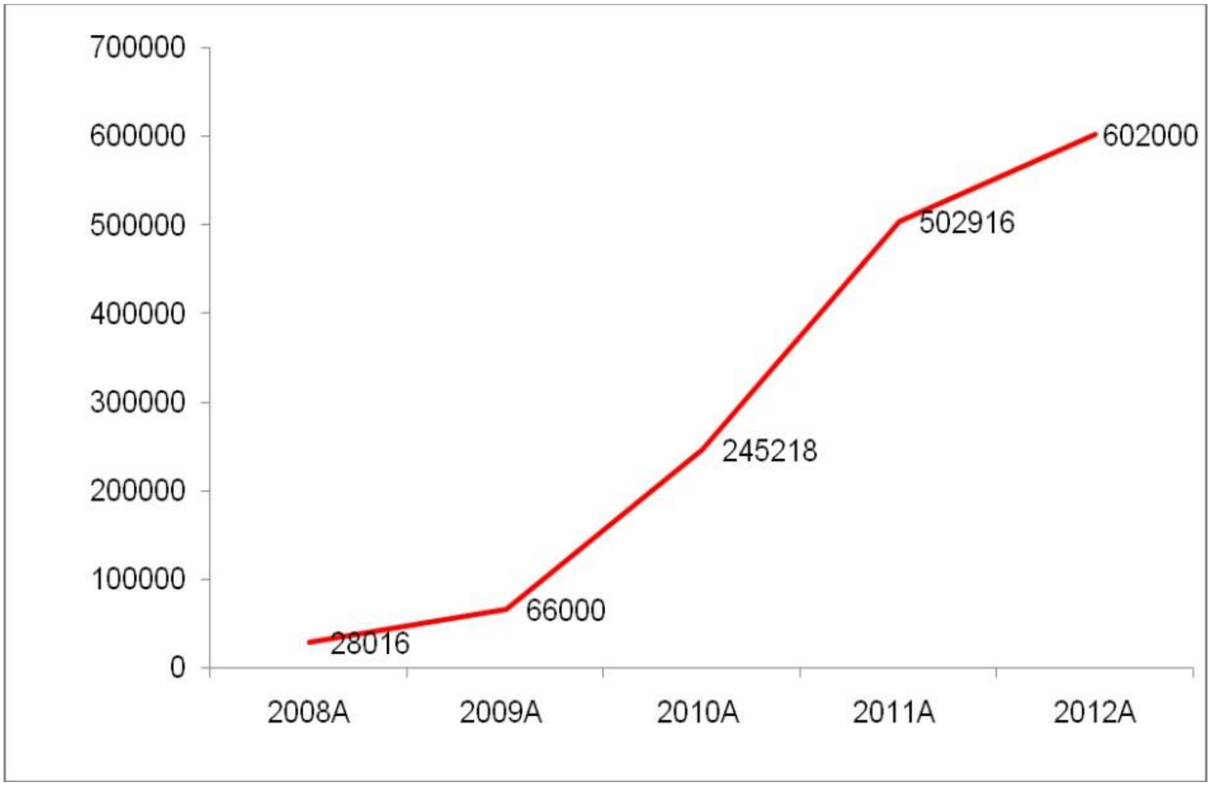


Figure 10**: Increase in LUC under priority crops (2008-2012)**

2.4.3.2 LUC worldwide

The process of land consolidation, "the method of reversing the action of land fragmentation," is not new in the World countries. In Britain, land consolidation took place so long ago, that many writers and even experts tend to forget that it took place at all (Pašakarnis & Maliene, 2010). Some of the earliest attempts at land consolidation, as a method of land reform, took place in Scandinavia, particularly in Finland (Hartvigsen, 2013), Sweden (Huang et al., 2011), Cyprus (Demetriou et al., 2012) and Denmark (Abubakari et al., 2016) in the 18th and 19th centuries. According to (Bouma et al., 1998), at least half of Western Europe's farmland was considered to need consolidation in the 1950s, a time when Europe had pressing needs of reconstruction after the Second World War.

Land use consolidation had also been implemented in Central and Western European (Pašakarnis and Maliene, 2010) countries since 1989 as part of an overall strategy of transition from centrally planned agriculture to privatization and market development in order to increase farmers revenues. It was also implemented in Latin America (Teubal, 2009), Asia (Niroula and Thapa, 2005) and Southern Africa (Asiama et al., 2017) to mitigate land fragmentation. In Kenya, the customary land tenure failed to meet the needs of an expanding population which then resulted in low subsistence levels and influenced land reforms needing land consolidation to stop further fragmentation in Kikuyu, Kiambu and Maranga Districts (Coldham, 1978).

2.4.4 Land degradation in Rwanda

Land degradation, as defined by the United Nations Convention to Combat Desertification, is the reduction or loss of the land's biological or economic productivity caused by human-induced land use processes (UN Ecosoc, 2007). Land degradation in Rwanda is characterized by soil erosion (i.e. loss of topsoil) and declining soil fertility. Although a widespread problem in east and central Africa, soil erosion reaches an extreme in Rwanda due to its steep topography, natural soil susceptibility to erosion and leaching and climatic conditions (Karamage et al., 2016). Land degradation manifests itself through soil erosion, water scarcity, reduced agricultural productivity, loss of vegetation cover and biodiversity, drought and poverty (UN Ecosoc, 2007).

Soil erosion results in a significant decline in soil fertility, which is the primary cause of low agricultural productivity in Rwanda. Heavily degraded soils are incapable of supporting large plant biomass because of low or depleted soil nutrients and soil organic matter (SOM). Organic matter is essential for maintaining soil structure and maximizing nutrient retention. It is the glue that holds soil nutrients, namely nitrogen and phosphorus in place until they are accessed by cultivated crops (Gordon et al., 2008). Frequent, continuous cultivation has accelerated the rate of SOM depletion in the country.

Moreover, soil erosion has substantial downstream impacts. High sediment loads reduce the size of river channels and water-holding capacities of lakes, choke water harvesting and storage systems, and exacerbate flooding (Gran et al., 2011). In addition, erosion is a major cause of progressive eutrophication in many of the country's lakes (Daniel et al., 1998; Ekholm and

Lehtoranta, 2012), promoting the proliferation of algal blooms and water hyacinth (Eichhornia crassipes), which reduce the amount of dissolved oxygen in water as it can be seen in the figure 11 below of Lake Cyohoha North.

Figure 11**: Water hyacinth (Eichhornia crassipes) growth on Lake Cyohoha North**

Several problems have been identified to be the route of soil degradation in Rwanda, which in turn has affected the depletion of the quality and quantity reduction of water resources. Lake Cyohoha (Figure 2-10) has been largely degraded, the causes of land degradation in Rwanda to be inadequate soil erosion control and unsustainable land-use practices (RADA, 2007).

2.4.5 Soil Conservation

In Rwanda, the initiative to prevent land degradation date back to the early twentieth century, when planting trees and constructing trench ditches were already being promoted to prevent erosion. Colonialists set warnings over over-grazing and over-cultivation threatening erosion and soil degradation (Olson, 1994). Today, the state encourages the construction of terraces to control soil erosion and reduce the loss of valuable top-soil (Mupenzi et al., 2012).

Traditionally, Rwandan farmers had settled on the higher ridges of hillsides because the soils were better there and farming was easier than it was down below in the swampy valleys and on the steeper slopes. The conventional agricultural system has undergone significant adjustments in recent decades due to rapid population increase. Due to land availability restrictions, farm holdings have decreased in size, become more fragmented, and cultivation has expanded onto bottomlands and fragile margins on steep slopes that were previously held in pasture and woodlot. Additionally, many households—particularly those with large families or little land ownership—now rent land. Lastly, fallow periods have gotten shorter and cultivation periods have gotten longer. The government has taken action to prevent and control soil erosion as a result of these causes putting strain on the soil (Berry et al., 2003; RADA, 2007).

The emphasis on bench-terrace policies as an effective way to combat soil erosion and to maintain water and soil nutrients is supported by experts. If well maintained, they can also improve land management and increase crop yields (Posthumus and Stroosnijder, 2010; Rushemuka et al., 2014). However, terracing on its own does not ensure increased production. It requires additional investments in inputs such as fertilizers, which farmers often find challenging to secure. Farmers also complain about the high labor input that is required to build and maintain the terraces (Bizoza and de Graaff, 2012). At present, farmers are encouraged to combine both mechanical and biological measures: terracing, contour bunds, trenches, and water retention systems at field level, fallows (although limited), hedgerows, intercropping, mulching and tree planting.

Additions to the array of conservation techniques include hedgerows planted with agroforestry species (e.g. Pennisetum purpureum), which are highly appreciated because they protect the soil and provide fodder for livestock. Zero grazing has been promoted because of its combined effects such as soil protection and integrated nutrient management through manuring, thus strengthening the (re)integration of cultivation and livestock production (Nabahungu and Visser, 2011; Shapiro et al., 2017).

2.4.6 The economic relevance of agriculture

Agriculture accounts for a third with 35% of the country's gross domestic product (GDP) (20092013) (FAO, 2015). Over the last 25 years, the agriculture sector has played a tremendous role in improving livelihoods of Rwandans and sustaining the country's economy. Recent statistics from the ministry of agriculture show that agriculture contributes 31% to the national GDP. It also covers 90% of food needs, generates 50% of the country's export revenues and employs around 70% of the population (MINAGRI, 2019). National economic growth projections are expected to depend heavily on the performance of the agriculture sector, which employs more than 80% of the country's population (Muhinda, 2013).

The agriculture sector also plays a vital role in national food production where more than 90% of the food produced nationally is consumed in the country. Although agriculture contributes significantly to the country's export revenues, Rwanda is still a net agricultural importer. Generally, tea and coffee are leading export commodities concentrating more than 90% of the export crops value. The main crops grown in the country are beans, banana, cassava, and maize, accounting for 18.1%, 17.3%, 9.2%, and 9.5% of total harvested area (2008– 2012). However, production of rice, maize, and beans do not meet the national demand, and therefore imports of these agricultural products are significantly higher (FAOSTAT, 2016).

There is an inclination for agricultural reinforcement due to heavy demographic pressure, resulting in a large amount of tiny and scattered farms. Small-Scale farmers (less than 1 ha) account for 72.4% of total farmers in the country. Since more than 70% of agricultural land is on hills or the side of hills and commercial agriculture is more difficult (NISR, 2017b). Currently, Rwanda is finding a way to transform its traditional agriculture sector to a modern method in order to have sustainable management of natural resources, water, and soil conservation. The strategies are being made to achieve the target including crop diversification and intensification and irrigation development (USAID, 2010; MINAGRI, 2017). In Rwanda, there are three agriculture seasons and each season has its specific crops grown in a particular portion as shown in table below.

Figure 12**: Rwanda agricultural seasons and main crops grown**

Season	Crop	Percentage (%)
Season A: Starts in September of one year and ends in February of the following year	Beans	27
	Bananas	19.7
	Cassava	12.6
	Maize	11.9
Season B: Starts in March and ends in July of the same year	Bananas	17.9
	Beans	17.4
	Cassava	15.9
	Sorghum	14.6
Season C: Starts in August and ends in September of the same year	Irish potatoes	71
	Beans	14
	Vegetables	12

Source: (NISR, 2014b)

2.4.7 Agricultural production systems and greenhouse gas emissions

Rwanda's numerous agro-ecological zones are home to a variety of agricultural production systems. Most of the mono-crops grown in the northern and western highlands include potatoes, tea, maize, wheat, climbing beans, and pyrethrum. The cultivation of bananas, maize, bush beans, sorghum, and cassava is well-known in the eastern lowlands. Farmers grow sweet potatoes, bush beans, tea, coffee, cassava, and wheat in the central and southern regions (Mutware and Mugabo, 2009).

Both small- and large-scale livestock farming is practiced, with cattle, sheep, goats, rabbits, pigs, chickens, and other animals typically raised in zero-grazing systems. The eastern savannah is home to the farmers with comparatively substantial land endowments (over 5 ha per farm) (Nyagatare, Gatsibo, and Kayonza districts). In the districts of Gasabo, Gicumbi, Kamonyi, and Bugesera, sugar cane is farmed in the Nyabugogo, Akagera, and Nyabarongo marshes (Mutabazi, 2010). Swamps around the nation are used to grow irrigated rice, and efforts to expand rice lands are continuous. The agriculture sector includes the production of tea, coffee, pyrethrum, sugar processing facilities, maize flour, soybean oil, packaged milk, and developing sub-products (WorldBank, 2018).

In comparison to regional and worldwide norms, Rwanda's total greenhouse gas (GHG) emissions are very low; nevertheless, trends indicate a minor increase since 2010. Nonetheless, a sizeable portion (39.5%) of the nation's overall greenhouse gas emissions come from the agriculture sector (USAID, 2018).

2.4.8 Rwanda Agriculture and Climate Change

The agricultural sector in Rwanda is particularly susceptible to risks associated with climate change and weather, such as protracted droughts (particularly in the eastern and southeast areas), mudslides (particularly in the northern and western regions), erratic rainfall, floods, and hailstorms. In 2008, there were 37% losses in maize output in the eastern province and 26% in the southern province due to the irregular rainfall. Drought-related milk production losses were projected to be 60% (Herve, 2019). According to research, shorter rainy seasons are having a negative impact on Rwanda's agricultural output as rainfall patterns become more erratic and unpredictable (Kabirigi et al., 2015). The average surface temperature of Africa has risen by 0.2 to 2.0 °C in the last 40 years (1970–2004), according to estimates from the fourth IPCC assessment report. Over the course of the next century (2010–2100), annual temperatures are expected to rise overall in Rwanda by 1.0 °C to 2.0 °C (IPCC, 2007). Rwanda has therefore adopted a proactive stance in integrating climate change into its strategies and programs for development. Climate change and variability are acknowledged as the biggest challenge and threat to the development agenda in key national development documents like Vision 2020, the Economic Development and Poverty Reduction Strategy (EDPRS), the Strategic Plan for the Transformation of Agriculture in Rwanda (SPTAR), and the Irrigation Master Plan (IMP) (CIAT, 2015).

2.5 Water pumping systems for agricultural irrigation

Water pumping system has a long history, and many methods have been developed to pump water to use for different purposes like irrigation, domestic use, industries with a minimum of effort (Mehrotra, 2013). The irrigation systems have the role of taking water from source, conveying it to individual fields within the farm and distribute it to each field in a controlled manner. Depending on elevation and location of water resources, two methods of irrigation can be used. When water surface is situated on higher slope, the gravity method is used while when source of water is underground or at low slop, the pumping system which is also known as pressure method is required to take water to the point of use (Basalike, 2015).About 85% of African water withdrawals are used for irrigation (Fischer, Tubiello, Velthuizen, & Wiberg, 2007).

In Rwanda, many projects are being studied on how to improve agriculture productivity by combating the effects of climate change such as droughts, irregular rainfalls, and landslides. One of the measures taken to deal with these problems is to put much effort into providing irrigation to hillside farms (Branca and Tinlot, 2012). There are some considerations such as land slope, soil permeability, and type, plot size and crops, water availability, required labor inputs and economic costs/benefit have to be analyzed before carrying out irrigation (Bidogeza et al., 2009). The most Rwandan cropped areas are irrigated using surface water resources by method of gravity, mainly for marshland areas.

However, some regions of the country showed to have a higher slope, and so it is impossible to apply gravity method of irrigation. Those areas include Bugesera district with an altitude varying between 1,100 m and 1,780 m. Bugesera is a hot district and is at the 17th position in the country to have a percentage of Households involved in agriculture and livestock activities. Crop farming and livestock are essential in the Bugesera district's economy where 77.8% of the population depends on agriculture, against 72% for national average (BDDP, 2013). Compared to other regions of the country, Bugesera district has dry climate with a temperature varying between 20°C and 30°C with an average ranging between 26°C and 29°C. In the past the district was turning into a dessert zone due to the extended drought period, that is why sustainable agriculture needs to enhance the irrigation system. This district has abundant water resources (rivers and lakes) and suitable average solar irradiation of 5.6 kWh/m2/day which may be used for irrigation (Walraevens et al., 2018).

2.6 Agriculture water resources

The available water resource is an essential criterion for choosing the kind of energy sources for any given water pumping application. Water can come either from groundwater or surface water. Surface water includes lakes, rivers, seawater, and rainwater whereas groundwater is found in underground aquifers, including springs. Spring and underground water do not commonly require treatment, except when it contains chemical substances such as salt and fluoride (Savci, 2012). Generally, the water treatment is not the main issue for irrigation purposes as long as it does not contain chemicals harmful to the soil and the crops (Ahmed et al., 2010).

According to Chang et al. (2001), the quality of the water is another crucial factor in identifying water resources. If the water is used as a domestic water supply, treatment may be needed. Nevertheless, water quality may be less critical for irrigation and livestock watering, except if it contains harmful chemicals. For example, Saltwater can burn some crops and damage soils (Francoisz, 1975).

Usually, agriculture requires the use of freshwater to irrigate crops. The primary water resources used for Rwanda irrigation system are runoff for small reservoirs, runoff for dams, direct river and floodwater, lake water resources, groundwater resources and marshlands (IPAR, 2009). Water is a fundamental asset for improving the livelihoods of smallholders and family farmers in Rwanda (Murugani and Thamaga-chitja, 2017). Sufficient availability and reliable access to water is crucial, not only to food production but also to social and economic development and sustainability. While investments in agricultural water management are a key to the increase of productivity of poor farmers and reduce rural poverty (Kamara et al., 2019), they often neglect considering the real needs and capacities of the local population or their market potential.

2.6.1 Agriculture water resources in achieving SDGs

Agricultural water management is an enabler and entry point for equitable and sustainable socioeconomic development in Rwanda. Enhancing access to water for agricultural production is to be strongly emphasized to ensure ecological sustainability. “Promote sustainable agriculture” is tacked onto the proposed Goal 2, “end hunger, achieve food security and improved nutrition” (Burchi & Holzapfel, 2015; UNICEF, 2016). The access to water for agriculture will play a crucial role, and the importance of improving agricultural productivity is to reduce poverty and hence, end hunger in Rwanda. A recent inventory of marshlands in Rwanda conducted in 2008 showed that Rwanda had got 962 water bodies and 860 marshlands, which has the potential for achieving water sustainability for smallholder farmers (REMA, 2008).

2.7 Summary of the Literature Review

In summary, based on the literature review, water resources are the sources of water that are useful for humans, as only a small portion (0.8%) of fresh water is available for use (Farinotti et al., 2019). Water is used for many different purposes, irrigation, domestic use, industrial use, and other human daily activities.

This research has focused on how changes in land use and land cover affect water resources. Lake Cyohoha serves the population for many functions, the main focus of this research is agriculture, this to ensure sustainable availability of water to smallholder farmers for irrigation in the future. Today the demand and consumption of water, food, and energy are increasing in the day to day life as the population growth increased. Several types of research have been done for studying the impacts of LULC change on environment in urban areas but failed to show its effect on water resources in rural areas where production is based on agriculture.

The research is built from a bank of knowledge which exists in this area. The research has associated land use, agriculture activities and the growth of population, leading to depletion of water resources, an example of Lake Chad. According to Niane et al. (2014), River Gambia has also experienced a reduction in size as a result of agricultural and mining activities along the river banks**.** The other study in Southern Africa has associated depletion of Zambezi water basin as a result of hydroelectricity projects and fishing according to (Pleasant, 1984; Kling et al., 2014). Also many studies in the Nile basin have shown the existence of poor catchment management from riparian countries, causing severe water shortages and pollution (Pacini and Harper, 2016).

So, the research addresses the knowledge gap which exists on Cyohoha Lake, its management, environmental sustainability, livelihood of communities and the influence of land use, land cover, and human activities. Also, this research tries to conceptualize the applicability of solutions which were posed from other studies such as creation of environmental community clubs, to monitor the protection and conservation of the catchment area in order to complement the Environmental Agency of Rwanda. This research is unique in Rwanda, Bugesera region, because there is no research which was done so far upon this problem, which has affected the local economic development of the area.

CHAPTER 3. RESEARCH METHODOLOGY

3.1 Introduction

This chapter covers all the techniques and methods that have been used for conducting this research. This section describes the methodology that was followed in the study to answer the research questions. This study was conducted using a mixed-method, research methodology, which integrated a quantitative and qualitative approach to better understanding of LULC changes and their drivers. Detection and analysis of drivers of LULC changes were conducted through a desktop study of LULC maps using Geographical Information Systems (GIS), interviewing catchments managers from both REMA and RWFA and Land Managers of the sectors within the catchment, document analysis and adapting the DPSIR framework. The desktop study of LULC maps was used to analyze LULC changes, and this addressed the objective of quantifying changes in LULC in the catchment of Lake Cyohoha. Interviews with catchments managers (Appendix 2) accompanied by reviews of documents were the methods used to determine driving factors and their impacts. An adapted Driver-Pressure-State-Impact-Response (DPSIR) framework was used to report and organize findings of the interviews into grouped themes presented as components of the framework. The sections below describe the sources of data, data analysis, population sample, research instrument and ethical considerations relating to this study.

3.2 Study area

The study area of this research is Lake Cyohoha North catchment, which lies in the Eastern Province of Rwanda. Due to poor management and repeated drought that occurred in 1999/2000, the Lake was about to dry up completely, which made the government and other institutions to start activities for the restoration of Lake Cyohoha North. The Lake Cyohoha catchment falls within the Akagera sub-basin of the more extensive Lake Victoria basin which is part of the Nile basin. The catchment covers watersheds that extend to an area of 508 km^2. It has an extensive wetland which is considered as a critical area under Ramsar Convention. Lake Cyohoha is 27 km long, and 5 to 2 km wide and is separated into two transboundary lakes, the southern and the northern Lake Cyohoha (GWP, 2016). The northern is estimated to 25km long and 0.30-1 km wide. Series of swamps up to 9 km separate the lake and the river Akanyaru, which is a tributary of the Akagera River, the biggest among 23 rivers that drain into Lake Victoria (Wali, 2011).

Lake Cyohoha is located in Bugesera Region. The dominant vegetation is dry savanna with short grasses, shrubs, and short trees; a characteristic of arid and semi-arid areas. The shrubs and short trees also surround the undulating hills, valleys and along the rivers and wetlands. The extensive savannas and their drought-resistant shrubs have historically provided grazing lands. The main types of ecosystems found in Bugesera are wetlands, water bodies, agricultural landscapes, savanna woodlands, and conserved rangelands. These ecosystems provide a variety of services for the people living in the surroundings of the lake. Lake Cyohoha and its wetlands, as well as the rivers, are the principal source of water for humans, livestock and wildlife. However, as previously mentioned, the lake and its wetland systems have been severely degraded due to agricultural expansion and settlement.

Consequently, with increasing population, most of the natural vegetation was converted into agricultural lands and over a time it disappeared. In terms of climate, the region is a low rainfall zone receiving an annual average of around 900 mm. Currently, the region is periodically faced with a persistent drought.

According to General population census 2022, Bugesera is one of the seven districts of the Eastern Province in Rwanda. It covers a total surface area of 1,288 km². The district is composed of 15 Sectors, in which 10 compose the catchment of Lake Cyohoha North with a total Population of 551,103.

Agriculture Development in the Lake Cyohoha catchment region is very high and expected to increase in future. However, since 1960, the region has experienced inflow of more People from within and outside Rwanda, which has progressively changed the demographic structure of the region. Most immigrants to Bugesera mentioned search for better agricultural lands as the main reason for migrating (UNEP, 2007). Population increase in the region with subsistence agriculture coupled with hunger caused by repeated droughts occurred in the region and low rainfall are significant issues in the Province. Such increase, coupled with continued in-migration, results in the growth of informal dwellings with characteristics of poor living conditions such as lack of access to essential services.

Furthermore, informal dwellings are located in unsuitable places which are often close to natural features such as wetlands and natural open space and hence, contribute to environmental degradation.

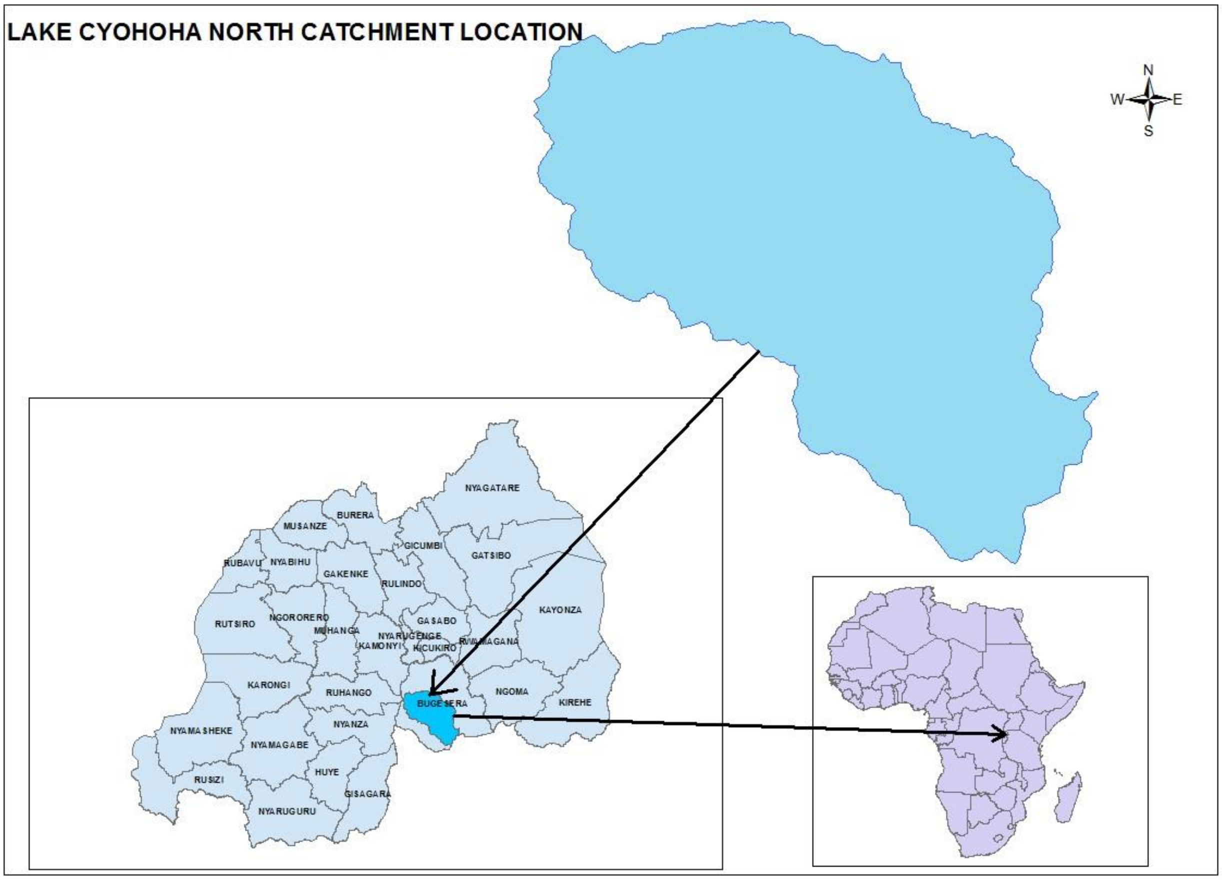


Figure 13**: Lake Cyohoha south location in relation to Rwanda**

Population growth in the Lake Cyohoha catchment, along with urbanization, increases pressure on natural resources, particularly land and water. The agricultural sector is a significant contributor to the economy of the region and is a crucial employment generator. However, expansion of agricultural activities harms the environment if it occurs at the expense of Critical Biodiversity Areas (CBA's). An analysis by the National Institute of Statistics of Rwanda (NISR) showed that a near-total conversion of wetlands, forests, and savanna woodlands into agricultural farms has occurred (NISR, 2017a). The Lake Cyohoha catchment is, therefore, faced with a challenge of weighing settlement development against agricultural expansion and protection of biodiversity areas to ensure better management of Lake Cyohoha.

3.3 Research Design

This study used both a qualitative and quantitative research design. Qualitative, as well as quantitative approaches, were employed to collect data. It has used both qualitative and quantitative approaches during sampling, data collection, and analysis. At data collection stage, Qualitative approach was used to collect ideas and opinions from farmers in an open-ended interview to the respondents where people provided their experiences in agriculture, while quantitative approach was used to collect responses from government institutions and nongovernment organizations in a closed-ended interview. A questionnaire has been used to collect numerical data and also observation method was used onsite to evaluate what was being done.

3.4 Population and Sample Size

This study was conducted in the catchment of Lake Cyohoha, Bugesera District, which was selected depending on increased degradation of the Lake while it sustains life of this region's people. Despite the availability of Lake Cyohoha, this region has recorded a problem of hunger and a significant number of families that are under a malnourished status. This study used sampling in order to obtain data from the field. A sample of 100 farmers in the catchment helped to simplify the work of the researcher by concentrating on a few respondents instead of covering many respondents. Further, two officers selected from RWFA and REMA, ten land managers and one reserve force were selected for interview. Sampling also helped to make generalizations due to the limited time of the research.

3.4.1 Sampling procedure and data collection

The study was conducted based on the survey in Bugesera district, Eastern Rwanda. The sample farmers were selected by utilizing a purposive sampling technique. From the total number of farmers that are using agriculture as their primary income source in the selected study areas, 100 respondents were taken from all Sectors which have their water flow to Lake Cyohoha: Musenyi, Nyamata, Rweru, Kamabuye, Ruhuha, Ngeruka, Mareba, Shyara, Nyarugenge and Mayange sectors. The summary of the number of respondents selected from study area is presented in Table below.

Table 4**: Sample size and sampling technique**

Category of respondents	**Sample Size**	**Sampling Technique**
Farmers	100 (10 each Sector)	Purposive sampling
Sector Land Managers	10	Taken from each Sector
Agronomists	2	Purposive sampling
NGO	1	Purposive sampling
Catchment management experts	2	Purposive sampling
Total	**115**	

To carry out this study, both primary and secondary data sources were employed. The primary data were collected by employing methods such as critical informant interview using semi structured checklist, expert interview; focus group discussion, semi-structured household questionnaire and observation of events. Secondary data that could supplement the primary data were collected from published and unpublished documents obtained from different sources. These included country policy statements, strategies regulations, reports, papers and journal on LULC and water resources. Items covered during the data collection were socio-economic situation of sampled farmers, land use and land cover change, land degradation, opportunities and barriers of using Lake Cyohoha for irrigation, demographic features, and the livelihood impact of irrigation activities. Discussions were also held with catchments management experts at the Rwanda Environmental Management Authority (REMA) and Rwanda Water and Forestry Authority (RWFA) and agronomists within the catchment.

3.4.2 Sampling techniques used

Simple random and purposive sampling techniques were employed to ensure that each member of the target population had an equal and independent chance of being included in the sample. Simple random sampling was used to select farmers from the districts of the catchment due to the large population size in this category, which warranted this approach to minimize sampling bias. Purposive sampling was used to select sector land managers, agronomists, NGO representatives, and catchment management experts, as this technique allows for targeted selection from smaller groups of informants.

3.5. Remote Sensing derived LULC data

3.5.1 Available LULC Data

The analysis of land use and land cover (LULC) change in the study area was based on directly comparable LULC datasets from 2013 and 2023, obtained from the Rwanda Water and Forestry Authority (RWFA). These datasets cover the entire country at a spatial resolution of 30 meters. The 2013 datasets were created by digitizing orthophotos taken in that year, while the 2023 datasets were produced by SARMAP, a reputable remote sensing company based in Switzerland, subcontracted by Esri Rwanda Ltd.

The datasets from both 2013 and 2023 were generated using optical satellite imagery (Landsat 8) and Synthetic Aperture Radar (SAR) data (Sentinel 1). The imagery was collected at regular intervals, specifically every few months, throughout each season to capture temporal variations in land cover and land use effectively. To validate the classification results, ground truthing was conducted through field surveys, where observations from specific locations were compared to the classified data. This process ensured the accuracy of the classifications by confirming that the satellite-derived information aligned with actual land conditions. The decision not to use supervised classification was made because the diverse and extensive nature of the study area made it challenging to define consistent training samples across various land types. Instead, automatic classification methods were utilized, as they were more efficient for processing large datasets and identifying broad land cover patterns.

3.5.2 Data processing and software

The 2013 datasets were classified into 8 classes and the 2023LULC datasets into eight classes. All datasets were reclassified or grouped into six classes for easy analysis and assessment of LULC changes. The classes are summarized below.

Table 5**: LULC Classification of the datasets**

LULC Class	LULC included	Description
Forest	Dense forest, Sparse Forest and Another tree covers (if appropriate)	Mainly natural forest, including some plantations with similar appearance and including unlogged or lightly selectively logged areas
Open areas	Open areas	Including parkland or savannah with detached trees, bushland or similar ecosystems, including areas of natural regeneration and young planted areas, and areas that have been heavily selectively logged but not clear-felled, or with scattered trees and shrubs

Agriculture	Banana plantation, Tea plantation, Coffee plantation, Hill-side perennial cropland, Hill-side seasonal/annual cropland without agroforestry, Hill-side seasonal/annual cropland with agroforestry, Valley irrigation/ drainage schemes: rice, Valley irrigation/ drainage schemes: other crops, Valley non-irrigated agricultural perennial cropland, Valley non-irrigated agricultural seasonal cropland, Open grassland, Grassland with scattered trees/savanna, Bush or shrubland, Other	Agriculture, grassland, clearings, including cropland, pasture, vineyards, nurseries, and natural grasslands or low herbaceous and shrubby vegetation. This class can be eventually disaggregated in terms of seasonality vs perennial
Bare Soil	Rock outcrops, Landslides, Quarries, and related degraded land	Barren land. This also includes bare soil associated with agricultural systems and other areas of bare soil, rocks, sediment deposits or landslides. It also included areas affected by clear felling or bush burning with little or no vegetation cover

Settlement and buildings	Urban/dense settlements, Urban/houses in individual gardens, Informal settlements, Industry, Semi-urban dense/Sparse settlements, Scattered buildings	Built-up areas, residential, commercial or industrial of all kinds
Water bodies	Rivers/streams (running water bodies), Lakes/ponds/reservoirs (standing water bodies)	Rivers/streams (running water bodies), Lakes/ponds/reservoirs (standing water bodies)
Mines	Areas with mining activities	Areas with mining activities
Unclassified	Unclassified	This category includes areas where data does not give a good image of the land cover or where the signal is unclear

Reclassification was done in ArcMap 10.5 using spatial analyst tools. It was performed to remain with inputs of LULC maps with matching classes, legend and characteristics. LULC change detection, quantification, and analysis were performed using Microsoft Excel that computed the changes and used to plot graphs. ArcMap 10.5 was therefore used to process the LULC datasets prior to analysis of the change detected. A Clip function in ArcMap was performed to create a new feature class of the Lake Cyohoha North catchment case study. This was followed by a copy of raster function to set resolution, and the Dissolve function was used to remove unnecessary boundaries between polygons. The workflow of reclassification in data processing in ArcMap is illustrated in the flowchart below.

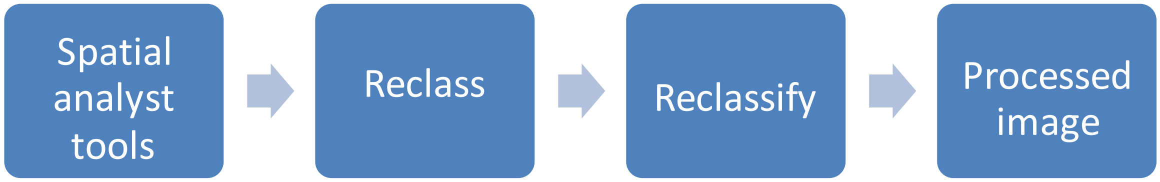


Figure 14**: Flowchart illustrating data processing in ArcMap 10.5**

3.5.3. LULC Change Qualitative Analysis

3.53.1. Population Sample

The research population for this study comprised catchment management officers from two institutions responsible for environmental management and water and forestry management in Rwanda. Participants were selected from each sector within the catchment, and they were required to have knowledge of land use issues relevant to their sector. This information is relevant to the sampling section but will not be included in it.

3.5.3.2. Research Instruments

Research instruments are tools used in the collection of data, such as interviews, questionnaires, observations and document readings. Whenever research instruments are used, the researcher needs to be sure that they provide accurate results on the topic of interest (Fagarasanu & Kumar, 2002).

3.5.3.3. Interview Guide

To explore land use and land cover (LULC) issues in the study area, an interview guide was developed as a flexible instrument for conducting interviews with both individuals and groups of key informants. This approach was particularly useful in areas where the researcher had limited prior knowledge.

3.5.3.2.1. Interview Structure

Semi-structured interviews were employed to gather primary data through interactions with planners and stakeholders. This method allowed for the exploration of relevant issues specific to the catchment area. Interviews were conducted both face-to-face and via telephone, with data collected through transcription and digital audio recording. Participants were informed about the research's nature, and a consent form was sent and explained before the interviews.

The interview guide (refer to Appendix 2: Interview Guide) outlined key themes, but the researcher, maintained flexibility during the interviews, using probing questions to delve into new topics that arose from respondents' answers. This approach facilitated the collection of detailed information on areas where the researcher lacked prior knowledge.

Data from the interviews were validated and supplemented with relevant LULC change documentation and questionnaires. Important documents, such as the Land Administration Developments in Rwanda, the Rwanda National Land Use Planning Guidelines, the National Land Policy, and the National Environment and Climate Change Policy, were sourced online and analyzed for pertinent LULC information.

3.5.3.1.3. Questionnaire

The questionnaires have been used to enable the researcher to balance the quantity and quality of data collected and also to enable respondents to provide information about particular questions with freedom by writing their opinions, views, perceptions, feelings, and experiences. This research could not achieve its intended objectives if the researcher had not approached farmers and heard from them to know the implications LULC change has on them and their concerns about the management of Lake Cyohoha.

3.6 Ethical Considerations

Identifying drivers of land-use change in the catchment of Lake Cyohoha required interaction with municipality catchments planners to understand how land-use decisions are made and how socioeconomic, political, and environmental factors interact to influence these decisions. (Munhall, 1988) stated that various ethical issues regarding information collection, seeking consent, providing incentives, sensitive information, harm and confidentiality must be considered in relation to participants. The following section addresses how ethical issues were handled in the research.

3.6.1. Informed Consent

The participants were informed before the interviews, of the purpose of the research, how they had to participate, why the information was necessary and why they were selected. A consent form was sent to all participants, and the researcher also read out and explained contents of the consent form before undertaking the interviews. Written consent was, therefore obtained from participants.

3.6.2 Privacy, Confidentiality, and Anonymity

The researcher acknowledges that sharing information about participants for purposes other than the research is unethical. Furthermore, confidentiality and anonymity are maintained by ensuring that participant names or any identifying information is excluded in documentations.

3.6.3 Voluntary Participation

Participants were informed of the purpose and nature of the research as a master's research project, and they were not forced to engage in the interviews. The informed consent letter also included a section where the participants were informed of their right to withdraw their contributions during the interview.

3.7. Data processing and analysis

Data were analyzed both quantitatively and qualitatively. The Answers/responses were grouped and analyzed using SPSS software and Excel programs. The information grouped under excel micro-software has been interpreted both quantitatively and qualitatively.

3.7.1. Qualitative data analysis

During data collection, qualitative data were categorized, and content analysis was performed to validate responses. Data from interviews were analyzed using the DPSIR Framework, ensuring alignment with the study's research questions.

3.7.2. Quantitative data analysis

After the collection of data, the following methods were used to analyze and present data.

i) **ArcGIS**: ArcGIS 10.5 software was used to extract useful information for the case study area and compute the statistics.

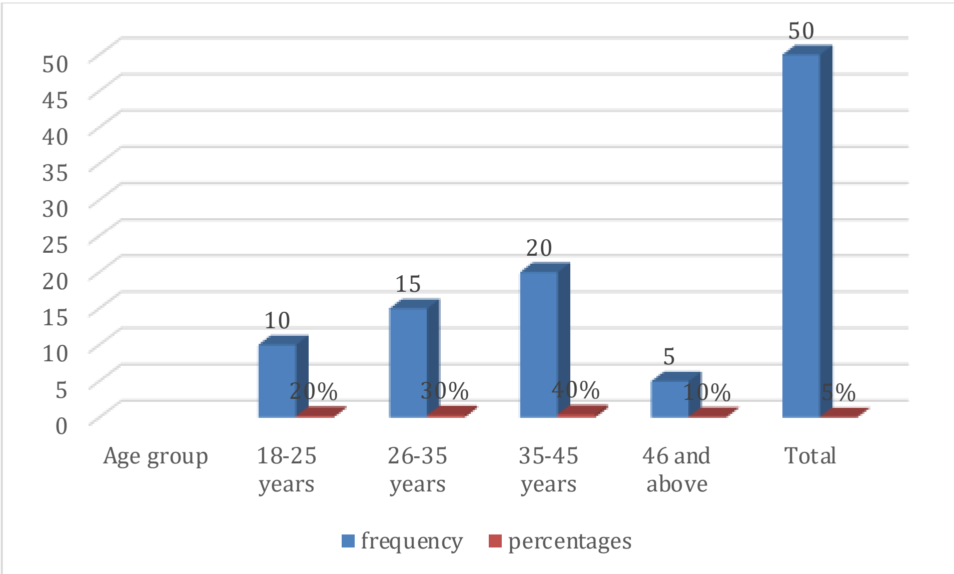
ii) **Microsoft Excel:** Ms Excel was used for data entry of collected data after field survey and to make graphs.

iii) **SPSS:** SPSS software was used for statistical analysis of qualitative and quantitative data.

The table below reflect the necessary quantitative data analysis aspects from SPSS, utilizing information gathered from research instruments.

Table6: Demographic characteristics of participant

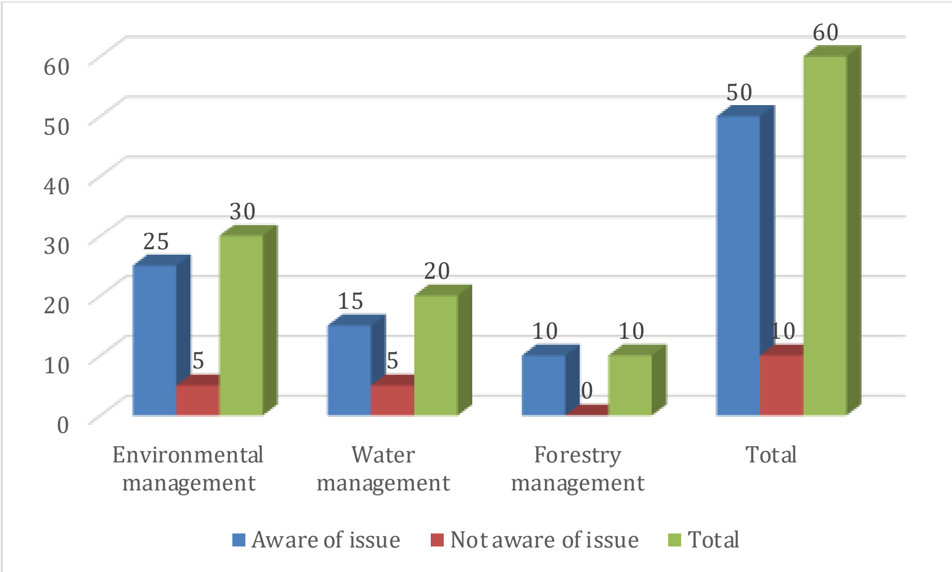
Characteristics	frequency	percentages
Age group		
18-25 years	10	20%
26-35 years	15	30%
35-45 years	20	40%
46 and above	5	10%
Total	50	5%



Source: Collected from structured interviews and questionnaires distributed among catchment management officers

Table7: Awareness of land use issues by sector

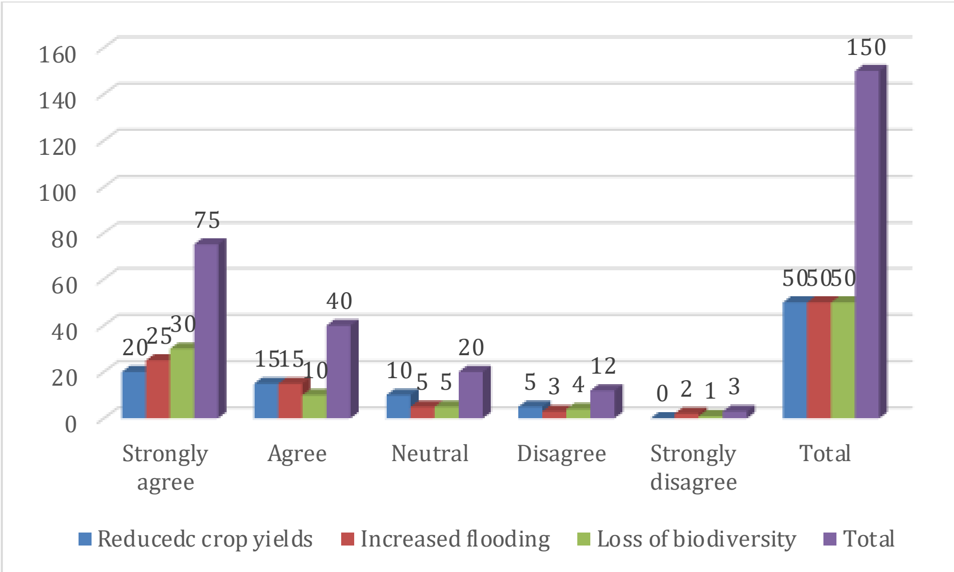
Sectors	Aware of issue	Not aware of issue	Total
Environmental management	25	5	30
Water management	15	5	20
Forestry management	10	0	10
Total	50	10	60



Source: Compiled from responses Collected during interviews with catchment management officers

Table8: Impact of LULC Change on livelihood

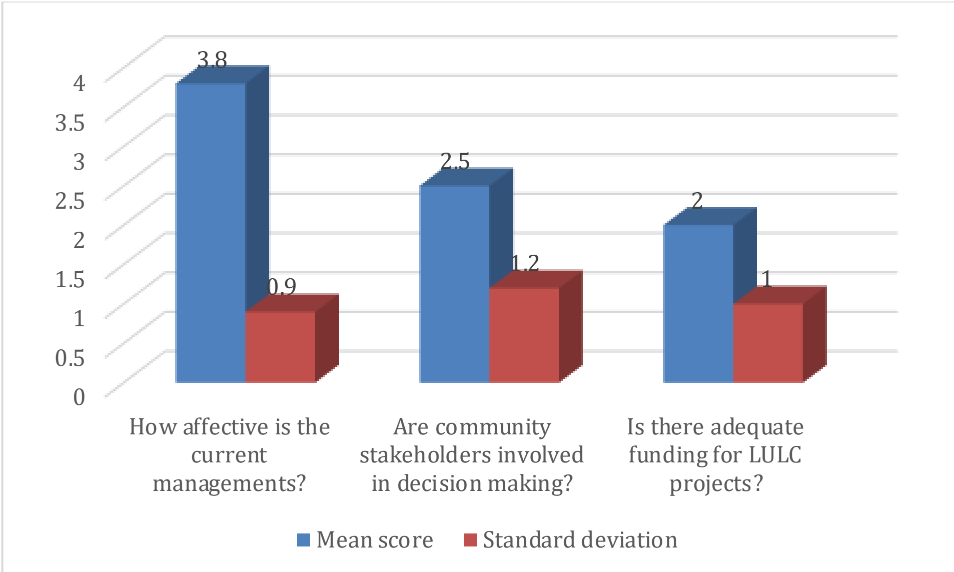
Impact type	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Total
Reducedc crop yields	20	15	10	5	0	50
Increased flooding	25	15	5	3	2	50
Loss of biodiversity	30	10	5	4	1	50
Total	75	40	20	12	3	150



Source: Results derived from both qualitative interviews and quantitative surveys concerning the impacts o LULC changes.

Table9: Response to questionnaire on LULC Management

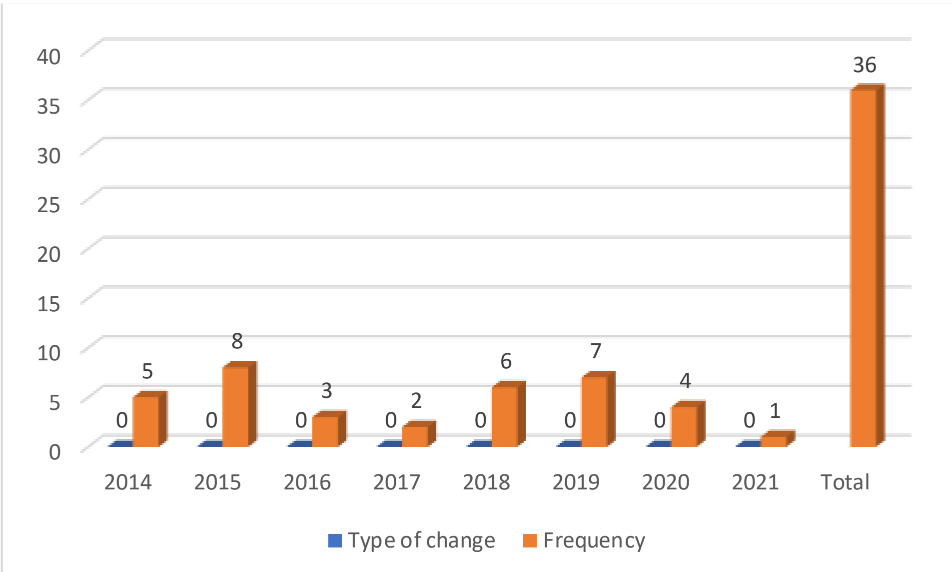
Question	Mean score	Standard deviation
How affective is the current managements?	3.8	0.9
Are community stakeholders involved in decision making?	2.5	1.2
Is there adequate funding for LULC projects?	2	1
Total	8.3	3.1



Source: Analyzed data using SPSS focusing on the statistical evaluation of responses collected

Table10: Frequency of LULC changes over the last decade

Year	Type of change	Frequency
2014	Urban expansion	5
2015	Agricultural expansion	8
2016	Deforestation	3
2017	Wetland degradation	2
2018	Urban expansion	6
2019	Agricultural expansion	7
2020	Deforestation	4
2021	Wetland restoration	1
Total		36



Source: Data analyzed through SPSS capturing the frequency of LULC change over the last decade.

3.8. Driver-Pressure-State-Impact-Response (DPSIR) Framework

The DPSIR is an analytical framework which can be used to organize, report, and illustrate the effects of human activities on the environment. This framework was developed by the European Environmental Agency in the 1990s and has been used for assessing interactions between different sectoral environment, demographic and social development (Patrício, Elliott, Mazik, Papadopoulou, & Smith, 2016). Today, DPSIR has been applied by international organizations (e.g., OECD, EU, EPA, and EEA) in environmental research projects to support planning decisions (Levrel, Kerbiriou, Couvet, & Weber, 2009). The DPSIR framework was adapted in assessing LULC changes in the study area in order to present various aspects and issues which emerged from interviews and document readings.

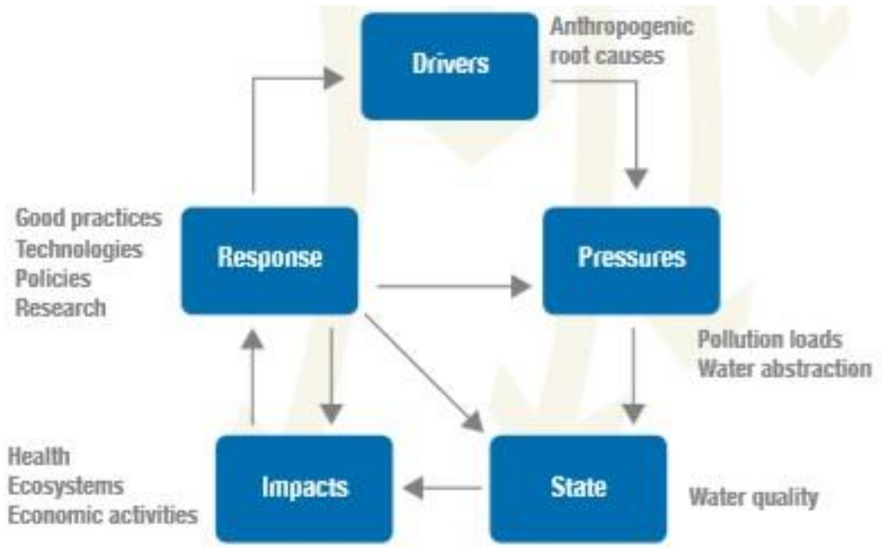


Figure 15**: DPSIR Framework and Water Quality (Javier et al., 2018).**

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.0. Introduction

This Chapter presents the results about the history of LULC changes which were observed in the Catchment of Lake Cyohoha North between 2013 and 2023. It consists of three Sections which provide qualitative and quantitative results obtained from the desktop study, questionnaire, interviews, and document analysis. This chapter is made by two main parts of this chapter which are the social demographics of respondents and the presentation of results and findings.

4.1 Social demography of the respondents

This subsection presents the social demographic data of the respondents by age, sex, level of education and employment status, in fact that respondents have given precise information, SPSS version 25.0 was used for analysis and the results are displayed in tables, and bar graph.

4.1.1. Identification of surveyed respondents by Age

Figure 16 is a bar graph that depicts the age of the respondents. It was observed that; 40% respondents were at the range of 21 to 35 years of age, 30%respondents were at the range of 36 to 49 years of age, 25% respondents were at the range of 50 to 63 years of age and 5% respondents were at the range over 63 years old.

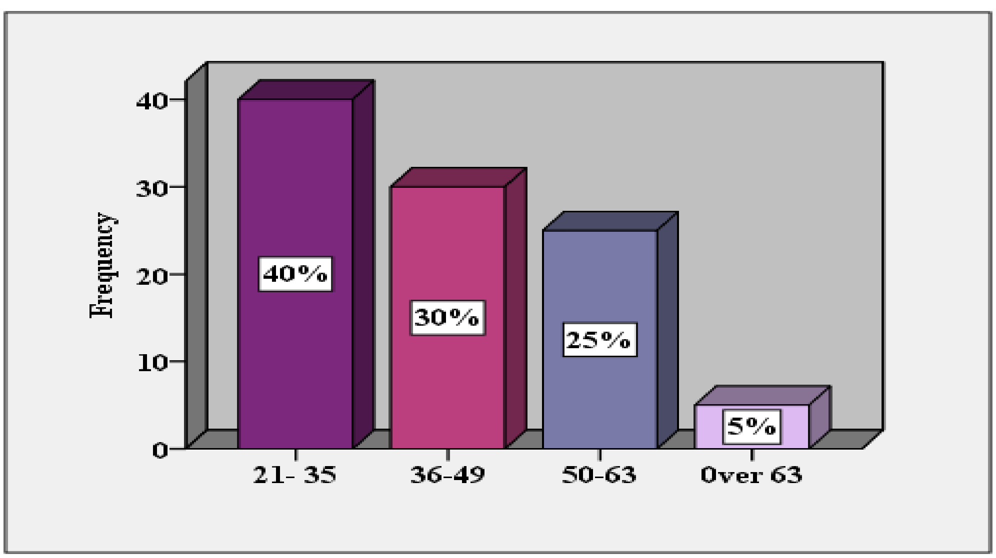


Figure 16: Age by respondents

4.1.2. Identification of surveyed respondents by gender

The figure 17 shows the identification of surveyed respondents by gender.

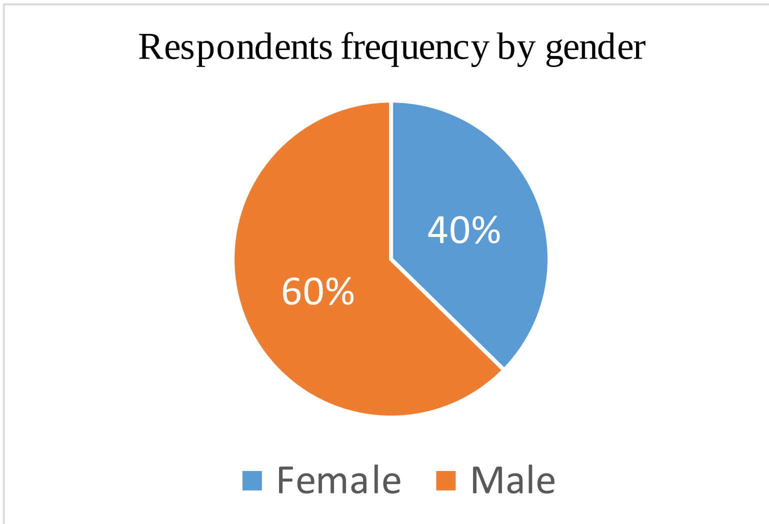


Figure 17**: Respondents by gender**

Figure 17 presents the respondents by gender. The surveyed respondents under this study were given equal opportunity where both male and female participated actively in providing responses. There was enough freedom to the respondents in answering the research questions. 40% of respondents were female, while 60 % of respondents were male. The researcher surveyed the respondents according to their gender in order to make comparison between male and female participation in this survey. The results show that a large number were male with 60% of respondents, because the questions asked were not gender sensitive. The difference in number between man and women doesn't have any significance.

4.1.3. Identification of surveyed respondents by marital status

The figure 18 shows the identification of surveyed respondents by marital status

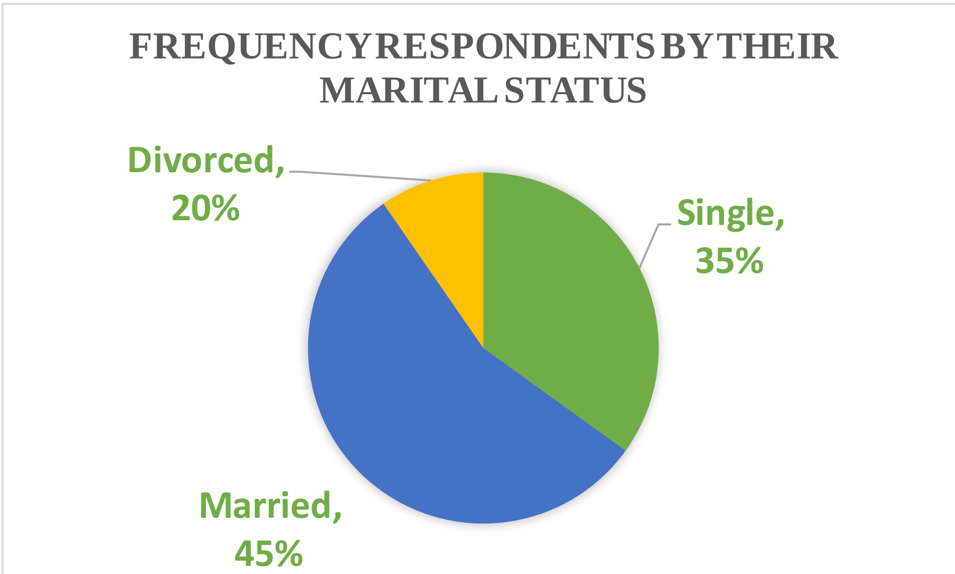


Figure 18**: Respondents by marital status**

Figure 18 illustrate respondents by marital status. In this study, 20% of respondents were divorced, and 45% of respondents were married, while 35% of respondents were still single. The researcher surveyed respondents in relation to their marital status in order to investigate the level land investment among different marital status. The results show that the married peoples invest in land at high level than single and divorced ones. This is because most of single people are interested in real estate investment for business or other reasons.

4.1.4 Level of education

Table 19 depicts the level of education of the respondents. It was observed that; 30% respondents have bachelor's level of education, 45% respondents have secondary level of education, 20% have master's degree and 5% have PhD.

Figure 19: level of education of the respondents

Level of education		Frequency	Percent
	Secondary level	45	45
	Bachelor degree	30	30
	Masters	20	20
	PhD	5	5
	Total	100	100

Source: Primary data, September 2024

4.2. Presentation of the major findings

This section deals with the presentation, interpretation and discussion of the real results from respondents interviewed face-to-face including the data collected through questionnaire for respondents' view related to the driving factors of LULC change in the Lake Cyohoha catchment from 2013 to 2023, the effects of LULC change in the Lake Cyohoha catchment from 2013 to 2023 and the impacts of LULC change in the Lake Cyohoha catchment on Smallholder farmers from 2013 to 2023.

4.2.1. Driving factors of LULC change in the Lake Cyohoha catchment from 2013 to 2023

This research identified both underlying and proximate driving factors of LULC change in the Lake Cyohoha catchment from 2013 to 2023. The findings shown that the driving factors of LULC change in the Lake Cyohoha catchment from 2013 to 2023 were infrastructure expansion, agriculture, and expansion and while underlying factors are political, economic, technological, demographic, environmental and cultural factors. The following frequencies and percentages were found according to the results from the field among the respondents of the study.

Table 11: **Driving factors of LULC change in the Lake Cyohoha catchment from 2013 to 2023**

Statements	Agreed		Undecided		Disagreed	
	Freq.	%	Freq.	%	Freq.	%
Infrastructure expansion	100	100	0	0	0	0
Agriculture	100	100	0	0	0	0
Political factors	100	100	0	0	0	0
Economic factors	100	100	0	0	0	0
Technological factors	100	100	0	0	0	0
Demographic factors	100	100	0	0	0	0
Environmental factors	100	100	0	0	0	0
Cultural factors	100	100	0	0	0	0

Based on the data collection through questionnaire and interview from the respondents of the project, all respondents were agree at 100% with the researcher that driving factors of LULC change in the Lake Cyohoha catchment from 2013 to 2023 are infrastructure expansion, agriculture, and expansion and while underlying factors are political, economic, technological, demographic, environmental and cultural factors.

4.2.1.1. Political Factors

As highlighted in the literature review on drivers of land-use change, legislation and policies significantly influence land-use changes in Rwanda. In urban areas, policies can either facilitate or obstruct development. A notable example is the Green City Development policy, which establishes the pillars of green and climate-resilient urbanism and demonstrates the viability of green cities in Rwanda. This policy aims to create sustainable, vibrant, affordable, and inclusive urban neighborhoods while protecting natural resources. In rural areas like the Lake Cyohoha catchment, land tenure administration laws are applicable. However, environmental protection policies face several challenges, including poverty and climate change. Catchment management planners and land managers must design actions based on local community capabilities, focusing on building their capacity to enhance awareness and management of natural resources.

4.2.1.2. Economic Factors

The economic development of the Lake Cyohoha catchment is closely linked to agriculture, tourism, and fishing, which the government prioritizes. The rationale is that high-potential sectors foster job creation and inclusive growth, allowing resources to be directed toward these areas rather than being spread thin across all sectors. This aligns with the Bugesera District's strategic goal of creating growth and job opportunities.

A significant percentage of Bugesera's population is rural and engaged in agriculture. Thus, modernizing agriculture and increasing productivity and revenue is crucial for improving their economic conditions. The Bugesera District has devised various strategies for this transformation over five years, including increasing land consolidation from 63,124 ha to 91,830.3 ha and expanding agricultural mechanization from 750 ha to 9,700 ha. Each sector will establish a mechanization center to facilitate farmers' access to machinery, enhance the quality and quantity of agricultural inputs, and ensure safe distribution management. This strategy aims to raise the use of chemical fertilizers from 10% to 30% and organic manure from 5% to 12%.

Additionally, the District is targeting improvements in soil conservation and protection through radical and progressive terraces, enhancing agroforestry programs, and developing marshlands from 1,422 ha to 3,422 ha. Plans include extending hillside irrigation systems from 124 ha to 1,774 ha, implementing long-term capacity-building initiatives for farmer cooperatives focusing on women and youth, adopting community-based nutrition programs with a variety of crops for kitchen and school gardens, and promoting public-private partnerships and risk management for value chains. The development of processing units for banana, rice, cassava, and maize is also prioritized.

Furthermore, enhancing the transformation of agricultural products to boost both quality and quantity of agricultural exports is a key focus. The establishment of more post-harvest facilities and agricultural research centers will complement improved horticulture and agribusiness programs aimed at export and cross-border trade.

The District is addressing apiculture and aquaculture productivity due to their significant potential. Strategies include equipping beekeepers with modern hives and establishing product centers. Increased quality in livestock farming and value addition to livestock products are also priorities. The District plans to enhance fish stocking in dams, ponds, and lakes to diversify agricultural practices. Livestock farming quality will be improved by enhancing cow breeds through artificial insemination and crossbreeding, transforming milk collection centers into dairy business centers, and empowering them to produce dairy by-products. Additionally, new valley dams will be constructed, and distribution of cows, pigs, and goats to poor and vulnerable families will occur, along with the establishment of modern farms and expansion of poultry farming. Veterinary laboratories for livestock disease control and comprehensive disease control programs will also be implemented. Emphasis will be placed on promoting agricultural financing through the development of agricultural entrepreneurship, establishing a fund for agricultural industries, and improving farmers' access to finance.

4.2.1.3. Demographic Factors

The Lake Cyohoha catchment is one of the most densely populated areas in Bugesera District, experiencing rapid population growth primarily due to natural increase and migration from other regions seeking fertile land. The district aims to increase urban settlement from 3% (EICV3) to 35% and promote organized rural settlements to improve service accessibility and urbanize major trade centers as poles of rural development. This will involve completing and implementing local development master plans for towns and trading centers, developing essential infrastructure to encourage grouped settlements, and establishing model villages with all necessary amenities, including disaster management systems.

The construction and extension of modern markets, as well as the development of cemetery sites and green spaces, will enhance the aesthetic and functional aspects of urban areas. Additionally, the establishment of Technical and Vocational Education and Training (TVET) centers will strategically benefit emerging towns and trading centers. Demographic factors, therefore, play a crucial role in driving land-use change.

4.2.1.4. Environmental Factors Climate change effects are evident in the Lake Cyohoha catchment, where extreme weather conditions, such as droughts, heatwaves, and floods, pose significant challenges to agriculture. These conditions necessitate increased food production to meet the demands of a growing population. Water availability is a critical factor impacting agricultural productivity in the catchment. Declining rainfall has led to reduced crop yields and profitability, exacerbated by the increasing conversion of land to agricultural use. The adverse impacts of climate change also affect other sectors reliant on agriculture for essential inputs. Moreover, dry and hot conditions trigger fires, contributing to plantation loss, while the reduction of forests and open land exacerbates erosion, leading to soil and water degradation.

4.2.1.5. Technological Factors

Environmental factors discussed above have led to severe and increased poverty of smallholder farmers due to reduced production and consolidation of farm units to achieve economies of scale. Consolidation of farms implies less reliance on labor and increased mechanization which results in job losses. Land consolidation has also implied a market problem. The transformation of agriculture from traditional low input technologies to modern systems by using increased fertilization and improved cultivars encountered challenges for areas prone to erosion which aggravate the issue of water resources degradation. Other factors include low education, skills and awareness levels.

4.2.1.6. Cultural Factors

Cultural factors significantly influence land-use decisions, shaped by people's beliefs and attitudes. Interviews with catchment management officers and land managers revealed that land-use decisions in catchments are primarily governed by land managers and local cell administrations. However, challenges persist in implementing planned land use effectively. A lack of knowledge and understanding regarding the impacts of specific land uses can adversely affect both environmental sustainability and economic viability.

4.2.1.7Results of the Study

The findings from the research indicate that various factors significantly influence land-use change in the Lake Cyohoha catchment. The following results summarize key insights derived from interviews, document readings, and quantitative data analysis:

1. Political Impact: Policies such as the Green City Development policy have demonstrated effectiveness in encouraging sustainable urban development, but challenges remain in rural areas due to inadequate enforcement and local community capacities.

2. Economic Drivers: Agricultural modernization efforts have shown positive effects on productivity; however, many farmers lack access to financing, which impedes the adoption of mechanization and improved agricultural practices.

3. Demographic Pressures: The rapid population growth in the Lake Cyohoha catchment has intensified land-use pressures, leading to increased agricultural expansion and urbanization, resulting in resource depletion and environmental degradation.

4. Environmental Challenges: Climate change effects, particularly water scarcity, have emerged as critical challenges affecting agricultural yields. Interview responses indicated that farmers face difficulties adapting to these changing conditions.

5. Technological Adoption: A gap exists in technology adoption among farmers, with many relying on traditional methods, limiting productivity improvements and exacerbating vulnerability to climate change.

6. Cultural Influences: Cultural beliefs and local governance structures significantly influence land-use decisions. Resistance to new practices due to traditional beliefs was noted as a barrier to sustainable land management.

These results underscore the complexity of land-use change dynamics in the Lake Cyohoha catchment and highlight the need for integrated approaches that address the interplay of political, economic, demographic, environmental, technological, and cultural factors.

4.2.2. LULC change in the Lake Cyohoha catchment from 2013 to 2023

Over the decade from 2013 to 2023, the Lake Cyohoha catchment saw substantial changes in land use and land cover (LULC). Agricultural land use expanded markedly, growing from 60.3% of the area in 2013 to 73.5% in 2023, mainly replacing areas that were once water bodies and natural vegetation. This shift reflects the combined impact of population growth, intensified farming practices, and limited regulatory oversight, which have prioritized agricultural needs over ecological preservation.

The reduction in water bodies from 30.3% to 25.7% during this period highlights the environmental pressures on the lake, affecting water quality and availability. Additionally, the loss of vegetative cover, which serves critical roles in maintaining soil stability and local biodiversity, poses long-term risks to the resilience of the ecosystem. These trends underscore an urgent need for sustainable land management to balance agricultural productivity with the preservation of water resources and biodiversity in the Lake Cyohoha catchment.

4.2.2.1. The status of Lake Cyohoha catchment in 2013

In order to analyse the status of Lake Cyohoha catchment in 2013, the land use and land cover map of Lake Cyohoha in 2013 was used. Below is the discussion on it

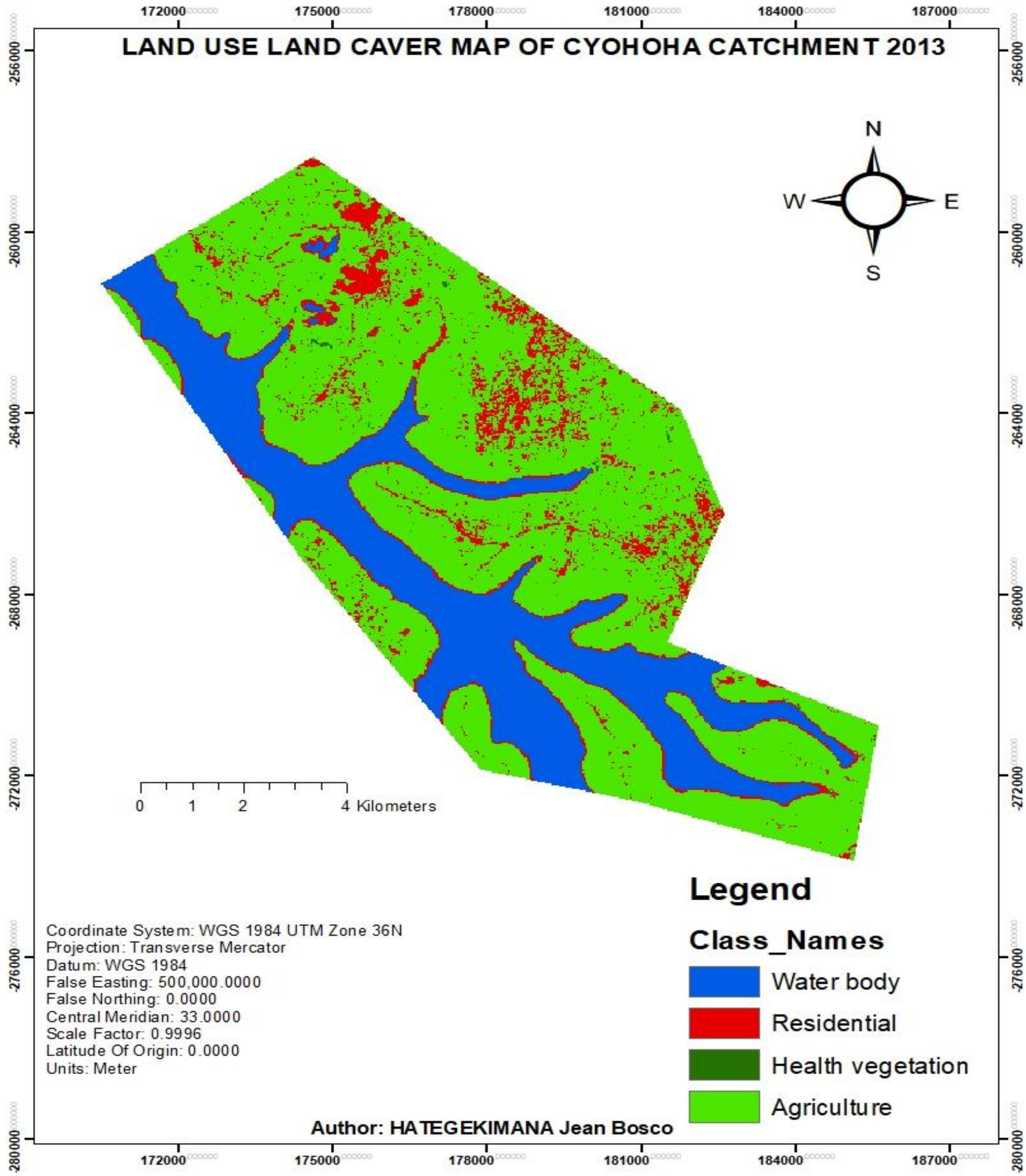


Figure 20**:** Land use and land cover map of Lake Cyohoha catchment in 2013

The figure 20 shows the land use and land cover map of Lake Cyohoha catchment in 2013. According to the land use/land cover map of Lake Cyohoha catchment in 2013 as presented above, the agriculture area represented by green colour covered large area than others land use types.

Table 12: Land use types of Lake Cyohoha catchment in 2013

LULC Types	**2013**	
	Area (ha)	**Area (%)**
Agriculture	4,694.9	60.3
Water body	2,358.87	30.3
Residential	632.5	8.2
Health vegetation	97.5	1.2
Total	7783.260772	**100**

The table 7 shows that in 2013, water body area covered 2,358.87 ha which is 30.3%, agriculture area covered 4,694.9 ha which is 60.3%; residential area covered 632.5 ha which is 8.2% while the health vegetation area covered 97.5 ha which is 1.2%. This implicates that agriculture land use area was at high level with 4694.9 ha and 60.3% of the total area of Lake Cyohoha catchment in 2013.

4.2.2.2. The level of Lake Cyohoha catchment in 2023

In order to analyse the status of Lake Cyohoha catchment, the land use and land cover map of Lake Cyohoha catchment in 2023 was used. Below is the discussion on it

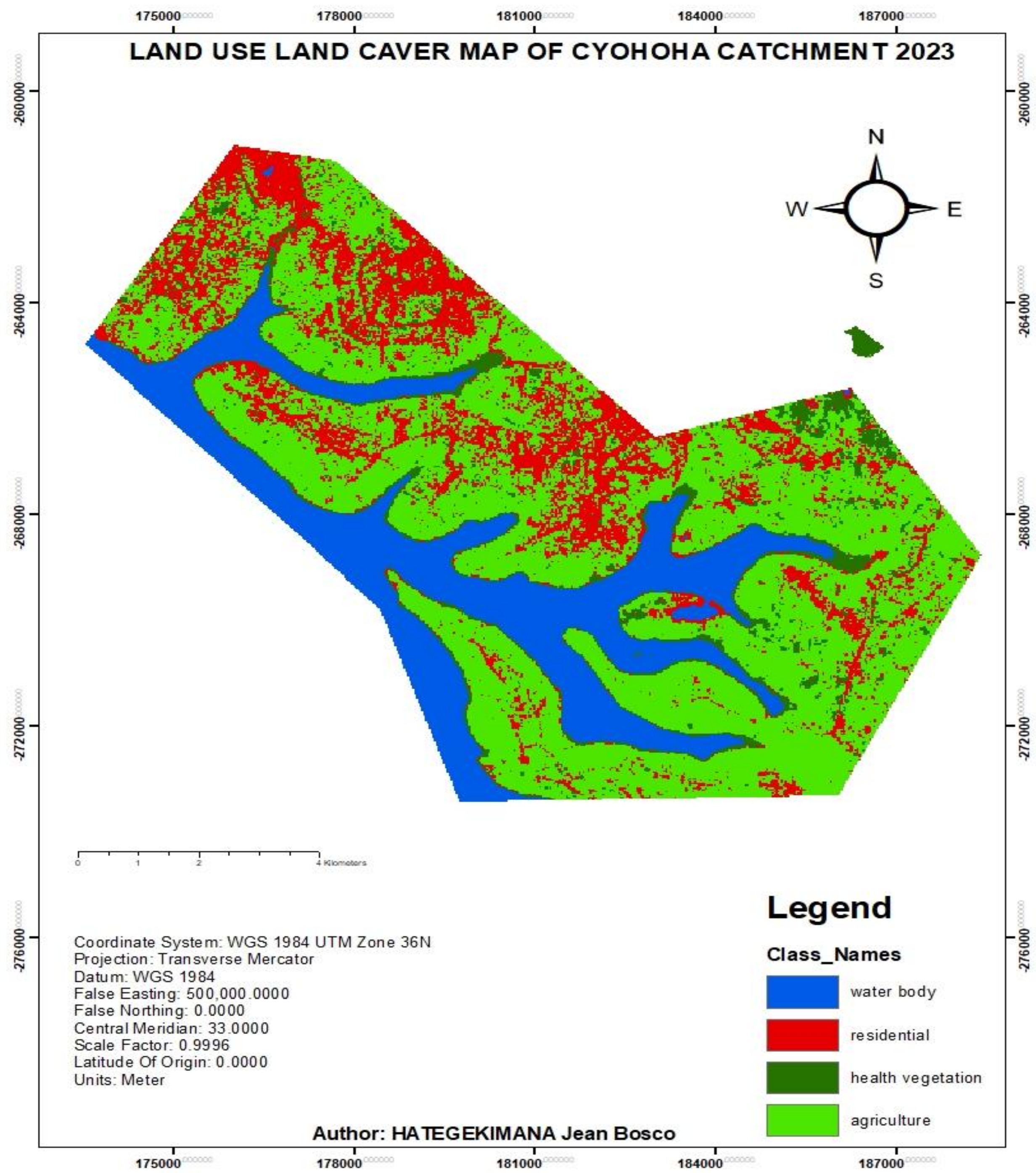


Figure 21: Land use and land cover map of Lake Cyohoha catchment in 2023

The figure 21, which shows the land use and land cover map of Lake Cyohoha catchment in the year of 2023.

Table 13: Land use types of Lake Cyohoha catchment

LULC Types	2023	
	Area (ha)	**Area (%)**
Agriculture	5,721.9	73.5
Water body	2004.5	25.7
Residential	36.1	0.5
Health vegetation	20.79	0.3
Total	7783.260772	**100**

The table 8 shows that in 2024, agriculture area covered 5,721.9 ha which is 73.5%, water body area covered 2004.5 ha which is 25.7%; residential area covered 36.1 ha which is 0.5% and health vegetation area has 20.79 ha which is 0.3%. This implicates that water body area covered 2004.5 ha with 25.7% of the total area of Lake Cyohoha catchment in 2023 and it was reduced in 202compared to the ones of 2013.

4.2.2.3. Change detection of land use and land cover of Lake Cyohoha catchment from 2013 to 2023

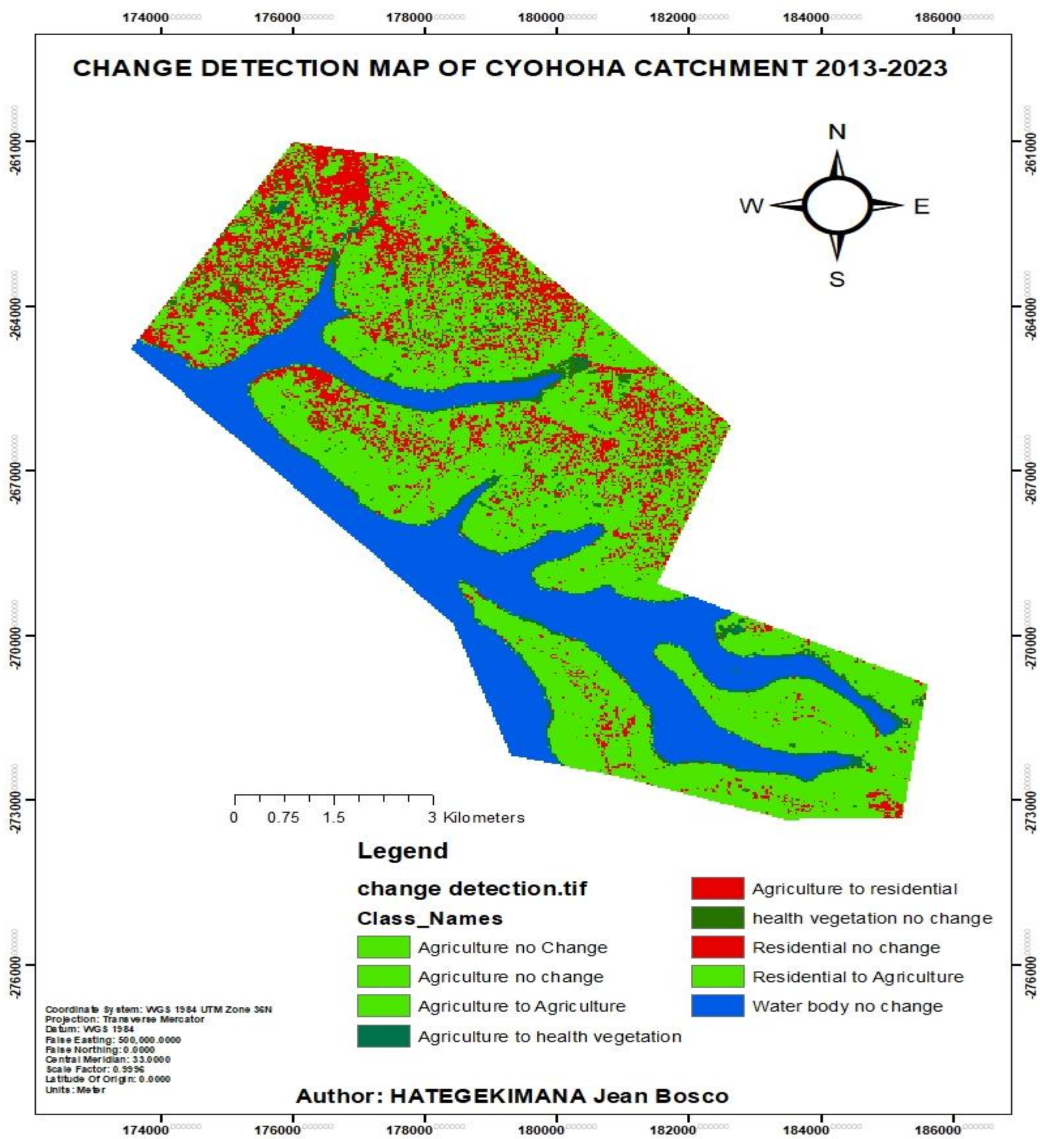


Figure 22: Change detection map of Lake Cyohoha catchment from 2013 to 2023

Based on the figure 22, land use land cover of Lake Cyohoha catchment undergoes with many changes from 2013 to 2023. Due to different factors such as infrastructure expansion, agriculture, political factors, economic factors, technological factors, demographic factors, environmental factors and cultural factors, Cyohoha Lake catchment show many changes from 2013 to 2023.

Table 13: Level to which land use land cover of have been changed between 2013 and 2023

LULC Types	2013 Area (%)	2023 Area (%)	Change from 2013 to 2023 Area (%)
Agriculture	60.3	73.5	11.2 (increased)
Water body	30.3	25.7	4.6 (decreased)
Residential	8.2	0.5	7.7 (decreased)
Health vegetation	1.2	0.3	0.9 (decreased)
Total	100	100	

As indicated by the table above, the types of land use land cover of Cyohoha Lake catchment have changed from 2013 to 2023. Agriculture area has increased from 2013 to 2023 at 11.2%. Water body area decreased from 2013 to 2023 at 4.6%. Residential area decreased from 2013 to 2023 at 0.5%. Health vegetation increased from 2013 to 2023 at 0.9%

4.2.3. Impacts of LULC change in the Lake Cyohoha catchment on Smallholder farmers Crop production from 2013 to 2023

Table 10 shows the results from a comparative analysis which was used to assess the farmers' crop production from 2013 to 2023.

Table 14**: Productivity from 2013 to 2023**

Quantity	Percentage before 2013	Percentage after 2023
1-2 tones	27	79
2-3 tones	62	20
>3 tones	11	1
Total	100	100

The findings from this study reveal that while the agricultural land in the Lake Cyohoha catchment increased, the productivity of crops has significantly declined over the past decade. As indicated in Table 10, the majority of farmers' crop production was concentrated in the lower yield categories, with 62% producing between 1 to 2 tons before 2013, decreasing drastically in higher yield categories post-2023. This outcome contrasts with expectations set by agricultural transformation efforts noted in prior studies, such as those by [Author et al. (Year)], which indicated that increased agricultural land use typically correlates with enhanced productivity due to improved farming techniques and technology adoption.

Despite Rwanda's commitment to agricultural transformation, challenges persist that resonate with findings from [Another Author (Year)], who identified similar issues in neighboring regions. Factors such as climate change, land degradation, and illegal agricultural practices have been shown to inhibit productivity improvements. The prolonged dry periods affecting the Lake Cyohoha catchment align with the broader trend of climate variability impacting agricultural sectors across East Africa, as described by [Third Author (Year)].

The illegal cultivation within the buffer zones established by REMA reflects a critical gap in policy enforcement and community engagement. Previous research, including [Fourth Author (Year)], emphasized the importance of sustainable land management practices and community involvement in mitigating environmental degradation. The findings in this study highlight the urgent need for interventions that balance agricultural needs with environmental protection.

Moreover, the detrimental impact of cutting papyrus on lake ecosystems echoes the work of [Fifth Author (Year)], which demonstrated that such practices lead to increased erosion and reduced biodiversity. These findings reinforce the necessity for integrated approaches that consider both agricultural productivity and environmental conservation.

In conclusion, while the study reflects certain trends consistent with previous literature, the stark decline in crop yields amidst agricultural land expansion underscores the pressing need for comprehensive strategies addressing both environmental sustainability and agricultural productivity in the Lake Cyohoha catchment.

Figure 23: Illegal agricultural activities in the buffer zone of the Lake Cyohoha North

Agricultural activities arrive in the water

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to investigate the impact that LULC change has on water resources and to analyze the implication that it has on smallholder farmers of the Lake Cyohoha North catchment. This chapter provides conclusions of the research based on the findings from the previous chapters. The sections below explain how the research objectives were achieved and suggest recommendations at the end.

5.1 Conclusions

This study investigates the effects of land use and land cover change (LULC) on Lake Cyohoha and its implications for smallholder farmers in Rwanda. The specific objectives were to determine the driving factors of LULC change in the Lake Cyohoha catchment from 2013 to 2023, to assess the effects of LULC change in the same period, and to evaluate the impacts of LULC change on smallholder farmers. The findings indicate that the primary driving factors of LULC change in the Lake Cyohoha catchment from 2013 to 2023 include infrastructure expansion and agricultural development. Underlying factors contributing to these changes are political, economic, technological, demographic, environmental, and cultural influences. As shown in Table 7, in 2013, the water body covered 2,358.87 ha (30.3%), while agricultural land comprised 4,694.9 ha (60.3%), residential areas accounted for 632.5 ha (8.2%), and healthy vegetation covered 97.5 ha (1.2%). This indicates that agricultural land use was significant, occupying 60.3% of the total area in the Lake Cyohoha catchment in 2013. By 2023, Table 8 reveals that agricultural land increased to 5,721.9 ha (73.5%), while the water body area decreased to 2,004.5 ha (25.7%), residential areas shrank to 36.1 ha (0.5%), and healthy vegetation diminished to 20.79 ha (0.3%). This reflects a reduction in water body area compared to 2013. Based on Figure 22, land use and land cover in the Lake Cyohoha catchment underwent significant changes from 2013 to 2023. Factors such as infrastructure expansion, agricultural development, and various political, economic, technological, demographic, environmental, and cultural influences have contributed to these changes. Overall, the data indicates a shift in land use, with agricultural area increasing by 11.2% from 2013 to 2023, while water body area decreased by 4.6%, residential area fell by 0.5%, and healthy vegetation increased by 0.9%.

5.2 Recommendations

This study represents the LULC change impacts on water resources for supporting the sustainable development of agriculture production in Rwanda. This section discusses some recommendations and the issues that require further investigation. From interviews and own observation, the activities for the restoration of Lake Cyohoha North are ongoing. However, the implementation is being done without any study done before to know what was the source of water quality and quantity depletion in Lake Cyohoha North. Though, the findings of this research prove that the main problem comes from agriculture that releases nutrients from fertilizers and pesticides washed away through runoff, which promote the excessive growth of water hyacinth and other aquatic weeds shown under previous chapters. Therefore, removing aquatic weeds without stopping the source of the problem would not provide long term answer. Thus, I call for REMA and RWFA to invest more in practices of managing the catchment and help farmers to control erosion in their farms for the sustainability of Lake Cyohoha.

Data availability is still a challenging issue for research in Rwanda. For example, datasets of LULC in the 1990s could not be found. The unavailability of datasets limits the accuracy of findings since it misses the past situation. Data is therefore recommended to both government and private institutions in order to support and encourage research and developments and to maximize data benefits to society.

Although the policy of land consolidation was introduced by the government of Rwanda, in Bugesera district it is still having low applicability and alerted smallholder farmers lack profit and market. It is one of the challenges. For this reason, more sensitization is needed to improve the skills of people about the use of land together (cooperatives). This also will help the farmers to put together their financial power to afford water pumping systems. Also, the government should strengthen regional integration and ease of access to local and regional markets.

Agriculture production in Lake Cyohoha North catchment depends mostly on rain-fed subsistence farming that is affected by unpredictable and erratic rainfall pattern which cannot guarantee enough food production for the population throughout the region which is under persistent threat of hunger. To improve the output at the farm level, effective harvesting of green water through increased infiltration and storage is needed and would be cost-effective.

Last but not least, the effects of climate change in the Bugesera region are a significant threat to the development of local communities who are mostly smallholder farmers. Thus, the government of Rwanda is highly recommended to introduce the incentives and subsidies for PVWP systems in spite of DWP for environmental and economic reasons. PVWP running cost is cheaper than DWP and more affordable by smallholder farmers, using PVWP could be an added value to benefit from excessive sun of this region and prevent CO_2 emissions in the atmosphere.

5.3. Future Works

Rwanda is a developing country that is growing fast; there are many needs in studying future LULC change and its impact on the development of the country that is environmentally safe. Future work on LULC change modeling in Lake Cyohoha catchment would be required to perform future predictions. This can be achieved with the availability of LULC data sets at shorter intervals and more accurate driving factor data at a regional scale.

Further research would be of more concern on Lake Cyohoha water quality to estimate the quantity of fertilizers and pesticides that farmers lose in every agricultural season washed away by erosion. The study would therefore call for immediate support from MINAGRI to help smallholder farmers control erosion for efficient use of the given inputs. Lake Cyohoha water quality assessment would also alert WASAC to supply treated potable water for the local communities living in this catchment who lack access to safely managed drinking water services and still use Lake Cyohoha water for domestic and drinking purpose.

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APPENDIX

Appendix 1**:** Structure of questionnaires for respondents

Field questionnaire for respondents

I, **HATEGEKIMANA Jean Bosco,** as finalist student at ULK Polytechnic Institute, department of Civil engineering and land surveying option. I am conducting a research entitled **"THE IMPACT OF LAND USE AND LAND COVER (LULC) CHANGE ON WATER RESOURCES AND ITS IMPLICATION FOR SMALLHOLDER FARMERS IN RWANDA. A CASE STUDY OF LAKE CYOHOHA NORTH (2013-2023)''.** Thus, this questionnaire will help to collect basis data for the research. This survey questionnaire has purely academic goals, and any information provided is confidential and will be utilized exclusively for the study. It would be greatly appreciated for offering me few minutes from your time for responding the following questions.

Section A: Biographical information of participants

Answering each question please put a tick on the right answer.

1) Kindly indicate your gender.

- ○ Female
- ○ Male

3) Kindly indicate your age group.

- ○ 18-30 Years
- ○ 31 -40 Years
- ○ 41-50 Years
- ○ 51-60 Years
- ○ Above 60 Years

4) Indicate your Level of Education

- ○ Secondary school
- ○ University level

- ○ Masters

Section B: Open questions

Please tick the most appropriate

1. What are the driving factors of LULC change in the Lake Cyohoha catchment from 2013 to 2023?

<u>Answer:</u>

- ❖ **The driving factors of Land Use and Land Cover (LULC) change in the Lake Cyohoha catchment from 2013 to 2023 include the following:**
- ➢ **Infrastructure Expansion:** Development of infrastructure, such as roads, housing, and public facilities, has driven significant changes in land cover, leading to urban sprawl and converting natural land into built environments.
- ➢ **Agriculture: Increasing** demand for agricultural land due to population growth has led to the conversion of forests and grasslands into farmland. The expansion of agriculture has been prioritized to support food security and income generation, often at the cost of natural ecosystems.
- ➢ **Political Factors**: Policies such as the Green City Development policy and land tenure laws have influenced LULC changes by promoting sustainable urban growth. However, in rural areas, limited enforcement and capacity have led to mixed outcomes in environmental protection.
- ➢ **Economic Factors:** Economic development efforts, particularly in agriculture, tourism, and fishing, have altered land use. Bugesera District's focus on enhancing productivity through land consolidation, mechanization, and commercialization of agriculture has reshaped rural landscapes.
- ➢ **Technological Factors:** The shift from traditional to mechanized agricultural practices, driven by increased investment in technology, has resulted in changes in land use. However, technology adoption remains inconsistent, with many smallholder farmers still relying on traditional methods.

- **Demographic Factors:** Rapid population growth has intensified land use demands, particularly in high-density areas. This pressure has led to increased agricultural expansion, urbanization, and demand for resources, driving substantial LULC changes.
- **Environmental Factors:** Climate change, with its impacts on water availability, droughts, and extreme weather, has influenced agricultural practices and land use decisions. These environmental pressures have forced land use adaptations, often with adverse impacts on natural ecosystems.
- **Cultural Factors:** Local beliefs and traditional practices shape land use decisions, especially in rural areas. Resistance to adopting new land management practices and limited awareness have constrained efforts to implement sustainable land use strategies.

2. What are the types of land use land cover of Lake Cyohoha catchment?

- **Types of Land Use and Land Cover in Lake Cyohoha Catchment:**
- **Agriculture:** Includes croplands, farmlands, and pasture areas.
- **Water bodies:** Such as lakes, rivers, and wetlands.
- **Residential areas:** Areas used for housing and urban structures.
- **Forest or woodland:** Dense tree-covered areas.
- **Grasslands:** Open lands dominated by grass vegetation.
- **Barren land:** Rocky, sandy, or otherwise sparse vegetative areas.
- **Wetlands**: Marshes, swamps, and areas with seasonal flooding.
- **Healthy vegetation:** Natural vegetation and green spaces, including conservation areas.

Thankyou!