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DEPARTMENT OF CIVIL ENGINEERING

OPTION: LAND SURVEY

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ASSESSMENT OF THE IMPACT OF POPULATION GROWTH ON FOREST DEGRADATION IN RWANDA

CASE STUDY GISHWATI FOREST (1990-2020)

Submitted in partial fulfillment of the requirement of the award of Advanced Diploma in Land Survey

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Kigali, September**, 2024**

DECLARATION OF ORIGINALITY

I'm NSANZUMUKIZA Benjamin 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 of Institution. I, therefore declare that this work is my own for the partial fulfilment of the award of the advanced diploma in civil engineering department, land surveying option at ULK Polytechnic Institute.

The candidate's names: NSANZUMUKIZA Benjamin

Signature of the candidate: …….

Date of submission: ……..

APPROVAL

This is to certify that this dissertation work entitled “Assessment of the impact of population growth on forest degradation using gis and remote sensing (1990-2020). Case study: Gishwati forest is an original study conducted by NSANZUMUKIZA Benjamin under my supervision and guidance.

The supervisor’s names: CIMANUKA BONGWA David

Signature of the supervisor: ……

Submission date: …….

DEDICATION

I dedicate this project to:

Almighty God

My family

My colleagues and friends

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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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ABSTRACT

Globally, human activities incurred from population growth have had great impacts on environment especially forest cover where deforestation have been so prevalent over last many years. This study aimed at analyzing the effects of population growth on the Gishwati forest degradation. The latter has been achieved by examining the trend in population growth and by integrating Remote sensing techniques and geo-information system platform to classify the land use land cover (1990-2020) through acquired satellite imageries. The findings revealed an increase in population growth where from 1990 to 2020, the population increased from 734654 people to 1381730 and the population density from 295.5 to 483.1 people per km^2. The above were in parallel with a decrease in forest cover (1990-2000) where forests have decreased (558.5 ha) at the expense of cropland expansion (496.5 ha). Moreover, the study has shown the success of restoration projects conducted in Rwanda, where from 2000-2020, the forests and grasslands trend have shown to increase with a decrease of cropland. Thus, the Rwandan government should be congratulated following its invested efforts put in Gishwati for its restoration and conservation leading to its nomination as a national park. Finally, the study suggests the creation of alternative way of generating income for people surrounding Gishwati forest, and design buffer zone to separate anthropogenic activities from the forest.

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LIST OF ABBREVIATION

UNEP	United Nation Environmental Program
REMA	Rwanda Environmental Management Authority
FHA	Forest Hope Association
MINIRENA	Ministry of Environment and Natural Resource
GoR	Government of Rwanda
GACP	Gishwati Area Conservation Project
GL	Gishwati Landscape
GAT	Gishwati Ape Trust
GIS	Geographical Information System
NGO	Non-governmental Organization
NISR	National Institute of Statistics of Rwanda
RS	Remote Sensing
PAs	Protected Areas
PAFOR	Projet d'Appui a L'Amenagement Forestier au Rwanda
GFR	Gishwati Forest Reserve
LULCC	Land Use Land Cover Change
UN	United Nation

DEFINITION OF KEY TERMS:

a. **Population:** Number of people living in area within a given period of time.
b. **Population growth:** is the increase in the number of people living an area over a given period of time. It is also the increase in the number of humans on earth. According to the human history our population was stable. But with innovation and industrialization, energy, food, water and medical care became more available. Global human population increased rapidly and continues to do so.
c. **Forest:** According to the Clean Development Mechanism (CDM) of the Kyoto Protocol, a "forest" is an area of more than 0.5-1.0 ha with a minimum "tree" cover of 10-30%, with "tree" defined as a plant with the capability of growing to be more than 2-5 m tall (UNFCCC 2002, Egenhofer and Fujiwara 2003). A forest also referred to as a wood or the woods, is an area with a high density of trees. what is considered a forest may vary significantly in size and have different classifications according to how and of what the forest is composed (Lund 2006, Gerdes 2008). Forest degradation is the reduction of the capacity of a forest to provide goods and services (Boahene 1998) and (Ahrends 2010).
d. **Forest degradation:** is broadly defined as a reduction in the capacity of a forest to produce ecosystem services such as carbon storage, provision services, regulating services, supporting services, cultural services and wood products as a result of human activities and environmental change. Forest degradation is a widespread global concern and an important issue for several United Nations (UN) organizations and conventions. these groups include UN conventions on Biological Diversity (CBD), which set a global target for Restoration of at least 15% of degraded ecosystems by 2020 ,(diversity 2010) the UN convention to combat Dissertation (UNCCD) that considers degradation on drylands, and the UN Frame Work Convention on Climate change (UNFCCC) that proposes to recover degraded forests.

CHAPTER ONE : GENERAL INTRODUCTION

1.0. Background of the study

The attempts to understand human population dynamics can be found back to(Malthus 1991), who clearly perceived the potential conflicts between the growth of the human population and the availability of resources (land and energy use, food production and water provision). After centuries of very slow unprecedented levels. As a result, world population more than doubled to 6.5 billion in 2005(nations 2007). This population expansion is expected to continue for several more decades before peaking near 10 billion later in the twenty-first century. Around 2070, the world's population will be 10 times larger than in 1 800. The recent period of very rapid demographic change in most countries around the world is characteristic of the central phases of a secular process called the demographic transition (bongaarts 2009)

Population increase has resulted to high pressure on natural resource in Rwanda. In many areas, there is an increase in local pressure to extend agricultural activities at the expense of forests and wildlife resources(madula 2001). As the population density increases, the supply of people who clear trees increase (wilson 1987) (Bank 1988, southgate 1988)and the demand for products from forests grows too. As a result of it, a larger forest area become deforested and leads to biodiversity loss. In addition to these forest changes, both the number of producers who use degrading agricultural or grazing practices increased(repetto 1986)). Likewise, the demand for crops and livestock produced with degrading practices increase. (Brown and Wolf 1984). Ethiopia with its 79 million (CSA 2001) people living in a geographical extent of 1.1 million km2 has a GDP of US $ 6.1 billion, 39% of which is contributed by Agriculture, upon which 85% of the population are dependent for livelihoods(Amare 2013). Forest is the important resource that provides many benefits to the society. In addition to providing woods, forest provide a habitat for wild life, site for recreation, materials for construction, watershed protection and many other benefits. It can also absorb atmospheric carbon dioxide (Dealon 1993).

The impact of demographic changes on forests and the environment is often discussed in terms of biological carrying capacity. i.e., the maximum number of individuals that a resource can sustain. However, many factors influence carrying capacity, such as economic development, socio-political processes, and trade, technology, and consumption preferences

(Bijendra 2009). A high population growth is a growing concern throughout the world and a challenge to countries' economies. The world's population was about a billion in 1800 and rise to 2.5 billion in 1950. In the year 2007 the world's population was 6.7 billion and is projected to rise to 9.2 billion by 2050 with almost all population growth projected to occur in what are now considered less developed regions. Between 1950 and 2000, when the world's population increased from 2.5 billion to 6.1 billion, the major shifts in population weights by continent were the result of changes in fertility and mortality rather than large-scale migration (kiguru 2013).

In addition, the problems with this approach have led to the realization that co-management and a greater role for local communities, the rural and urban poor, as well as the private sector in the management of forests is needed (Matiku 2013). In Rwanda the main drivers of forest degradation are: Agriculture, with 95% of households practicing traditional subsistence agriculture on small plots that have degraded soil structure and fertility due to continuous cultivation, Infrastructure development, Urbanization including the growing of built-up area, which increased by over 300% in the period from 1990 to 2016, artisanal mining practices, with a high increase in issued mining permits in 2014 a total of 548 mining permits were issued to 213 registered mining entities but no restoration of abandoned mining sites, Forest product extraction, mostly firewood, charcoal and timber and Limited forestry extension services (Rutebuka, Zhang et al. 2018)

1.1 Problem statement

As the population in the regions surrounding Gishwati has increased, so too has the pressure on the forest's resources. This pressure manifests in various forms, each contributing to the overall degradation of the ecosystem. Agricultural expansion, driven by the need to feed a growing population, has led to the conversion of forested land into farmland (Westberg 2023)Simultaneously, the demand for settlement areas has resulted in encroachment into the forest, with new housing and infrastructure replacing trees and wildlife habitats.

The growing population has also intensified resource extraction from the forest. Increased demand for timber, firewood, and non-timber forest products has led to unsustainable harvesting practices (Munanura, Backman et al. 2014)Moreover, as livestock populations have grown to meet the needs of more people, grazing land has expanded at the expense of forested areas. The development of roads and other infrastructure to support the burgeoning

population has further fragmented the forest, disrupting ecological corridors and habitats (NYANDWI, Rwanda et al. 2011)

1.2 Objectives of the study

1.3 General objective

To assess the impacts of population, increase on forest degradation in Gishwati forest in western province of Rwanda.

1.4 Specific Objectives

The specific objectives of the study are:

1. To assess the trend of population growth in the study area.
2. To analyze the extent at which Gishwati forest is being degraded.
3. To discuss the impacts of population growth on forest degradation.

1.5 Research questions

1. How is the trend of population growth in the study area?
2. At which extent Gishwati forest has been degraded?
3. What are the impacts of population growth on Gishwati forest degradation?

1.6 Significance of the study

The study is important since it assesses the nexus between human activities and the degradation of Gishwati. It shows also the activities that should be done to continue conserving and protecting Gishwati forest.

To the government; First. it will help the government, REMA and forestry authority to develop better and efficient strategies to deal with the increasing demand for forestry products.

- More approaches and policies will be developed that enhance community participation in decision-making process of forest conservation or management.
- It will also create awareness about the plight of the forests and population dynamics in the communities

Socially, findings from this research will help in increasing community awareness about the value and the importance of Gishwati on human livelihoods but also awareness on effects from their daily activities towards the Gishwati forest ecosystem quality.

Scientifically, this study will enhance the better understanding of various anthropogenic activities posing threats to the nature of Gishwati in the correct condition to serve to the environment sustainability. In adding to that, findings from this study will also help future environmentalist's researchers to be interested in forest conservation and its protection, specifically in reducing impacts from its degradation.

Academically, this study will significantly be an effort in learning institutions by taking into account of findings, results and recommendations that will contribute to the thinking of the community towards the surroundings environment

1.7 Scope of the study

In space**,** the study considered the Gishwati forest in West province of Rwanda crossing the Nyabihu, Rubavu, Rutsiro and Ngororero Districts.

In time, this study will cover a period from 2011 to 2021, a period that the researcher should get enough information on communities living near and around the Gishwati. The researcher judged this period to be enough to evaluate and determine the population growth linked to the forest degradation over time.

In domain, the study will not go beyond Gishwati forest conservation and moreover the study is more linked to the environment management and conservation.

1.8 Conceptual framework

The conceptual framework is the researcher's understanding of how the particular variables in her study connect with each other. Thus, it identifies the variables required in the research study. Where, population growth is independent variable while forest degradation is dependent variable.

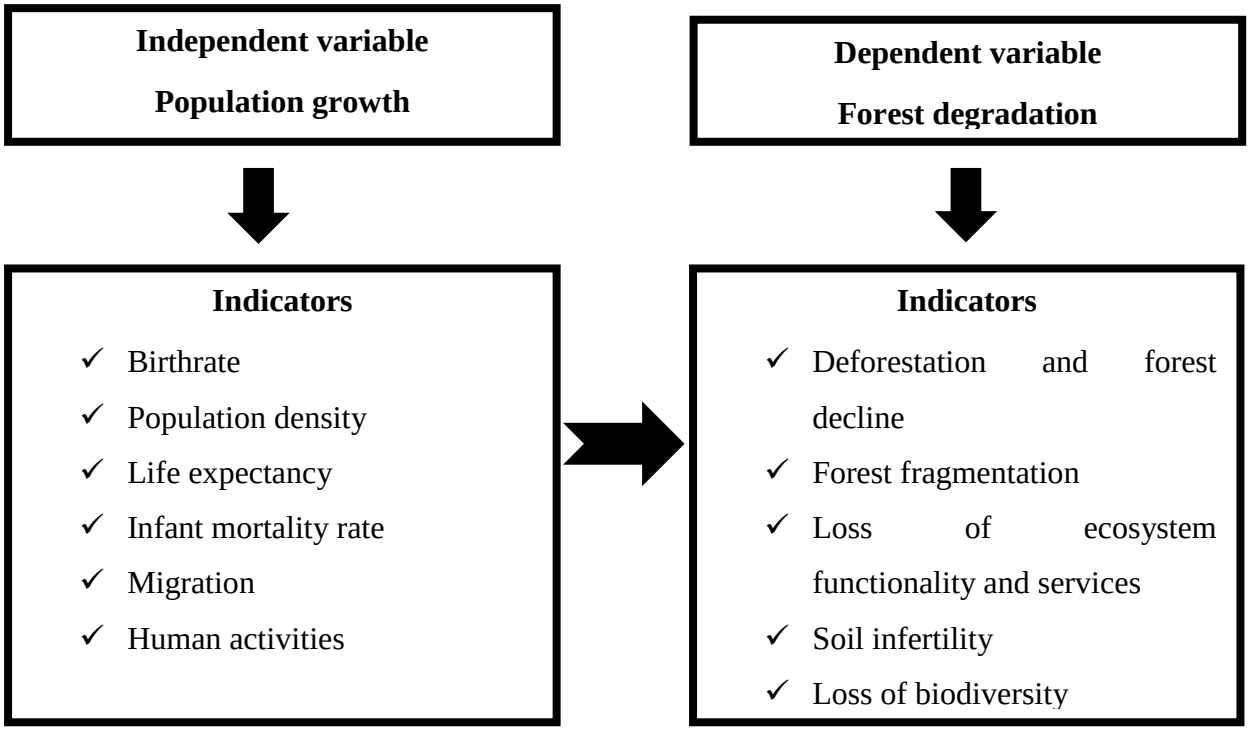


Figure1. 1.Conceptual framework

1.9 Organizational of the study

This study will be categorized into five (5) chapters: which are:

The introduction as the **first chapter** consisted of the general introduction, background of the study, problem statement, the general and specific objectives of the study, research questions, significance of the study, and scope of the study, conceptual framework and finally the organization of the study.

The **second chapter** covers the definition of keys concepts and literature review.

The **third chapter** concerned with the Research Methodology, which include, research design, population of the study, sample size, sampling techniques, research instrument (questionnaires, interview guide). Data collection procedure and data analyses, and finally the limitations of the study.

The **fourth chapter** covers the presentation of the results and discussion of the findings.

The **last chapter** shows general conclusion and recommendations

CHAPTER TWO. LITERATURE REVIEW

2.0 Introduction

This chapter focuses on the review of related literature about the independent variable (population growth) and the dependent variable (forest degradation) through the specific objectives by finding out the causes of population increase, identifying the effects of population increase to forests, exploring the population control measures within the nearby communities and suggesting suitable forest conservation strategies put in place to reduce population increase

2.1. Population growth

2.1.1.Causes of population growth

Until recently. birth rates and death rates were like the same, keeping the population stable. People had many children, most of them died before age five. During the Industrial Revolution, a period of history in Europe and North America where there were great advances in science and technology, the success in reducing death rates was started such as increases in food production and distribution, improvement in public health (water and sanitation), and medical technology (vaccines and antibiotics), where the standard of living within nations developed. (kinder 1998).

Lack of access to family planning and modern methods of contraception is a major cause of the persistence of high population growth as indicated by the prevalent in most less developed countries having the requisite data(peter 2012). This made countries to have an increase in their population (kinder 1998). Improvement in public health firstly through lack of access to clean and safe drinking water was related to the incidence of epidemic diseases such as cholera and child survival. Less than 50% of the population had access to safe drinking water before 1990. By 1990, access to safe drinking water had increased by 75 percent but between 1990 and 2000 the numbers of people without access to safe water were projected to increase. Second, the pressure to provide adequate housing increases as the population increase. More than half of the developing world's population was projected to live in urban areas by the end of the twentieth century. This growth exceeds the capacity to provide housing and services for others.

Socio-demographic characteristics of the population, mortality patterns, migration patterns, fertility, the proportion of women in a union, contraceptive use, breast feeding practices, conflict, regional/national population policies, and their implementation strategies and social issues. Of the above-mentioned factors, mortality, migration and fertility are the core influential components of a population increase of every country (Maluleke 2011). A contributing factor to the African population size is the youthful population. The size of the African population in the youthful ages is responsible for coupled by non-contraceptive use, the higher the probability of increased birth rates. In 2009, the population reference bureau has estimated that 43 percent of sub-Saharan African population is below the age of 15, a phenomenon which shall influence Africa's population growth.

Another important factor is vaccinations. As far back as 1800, scientists knew how to use vaccines to protect people from infectious disease. Use of that knowledge has reduced the rate of diseases. Again, lack of resources has prevented many LDCs from making similar use of vaccinations to reduce the rate of infectious disease and death rates in their countries. Moreover, vaccines are still not available for some diseases like malaria is the most easily discovered example and the greatest concern in LDCs. Better public health practices for instance the microorganism theory of disease, discovered by Louis Pasteur in the 1 870s clearly demonstrated that a person's health was also a community problem. Sewage dumped into a public water supply could cause disease throughout the community. With this understanding, the science of public health was born. Today, public health measures like waste treatment, water purification, vaccination, and nutritional education are well developed in MDCs. However, public health measures are still absent in many LDCs. As a result, disease continues to spread and cause high death rates. And finally, with the advent of new medicines, disease was less of a problem in MDCs. because medical science has invented a whole range of new medicines with which to treat everything from infections. In many LDCs, new drugs and medicines are simply not available, and if they are available, they are too expensive.

2.1.2.Effects of population increase on forests

The relationship between population growth and environment are often complex. As the world's population increase, more food is needed to the human being, the community search land for agriculture through deforestation to create new farmlands. Reliance on mechanization, pesticides, and chemical fertilizers, such practices can be associated with soil erosion. As well, the agriculture runoff release excess fertilizers which causes eutrophication and harms marine life. Deforestation leads to a reduced ability to capture co2, thus increases greenhouse gases problem, and is associated with loss of habitat and extinctions (Weyman 2011).

Human population growth and climate change have grown hand in hand. More people, more demand for oil, coal, gas, and other energy resources extracted from the earth's surface that release carbon dioxide into the atmosphere when burned. forests store more than twice the amount of carbon dioxide than is found in the atmosphere. As forests are cleared and burned, that co2 is released into the atmosphere, where it is estimated that 12 percent of total greenhouse gas production. Deforestation and forest degradation are critical issues, threatening biodiversity, ecosystem stability and the long-term availability of forest products as well as depleting the natural resource base underpinning many national economies(ADB 2000) . Population pressure, heavy dependence on fuelwood, timber and other products, as well as conversion of forests to agricultural, urban and industrial land are the underlying factors for deforestation in the region.

Forest degradation and deforestation has also resulted from overgrazing and shifting cultivation. in addition, as forests have become degraded, so fire, pests, diseases and natural disasters have caused greater damage. Construction of irrigation schemes, dams and reservoirs as well as mining are further causes of deforestation(ADB 2000a) .

2.1.3.Effects of population increase to Gishwati forests

The increase in population around Gishwati areas during the 1980s which led to an increase in livestock numbers hence increasing demand for grazing, settlement, cropland and fuel wood (MINITERE 2007). In addition, from 1978 to 1994 the principal causes of deforestation were the objectives of converting the bamboo trees into pasture land, pine plantation(Seylar 2002).

Exploitation of the forest for commercial products such as charcoal, timber, medicine, and food has been the main driver of this deforestation. 1978 satellite image shows the Gishwati Forest Reserve as a Dark Green of dense forest. The 2006 image shows that most of the forest has been cleared, Resettlement of returning refugees in the after 1994 Genocide against the Tutsi saw the loss of the remaining natural forest to settlements and agriculture. In 1999 the resettlement of 818 families on a 3,000ha site called Arusha in Gishwati. Even before deforestation about 2/3 of Gishwati forest had already been converted into pasture and pine plantation by World Bank project in the 1980s. As settlement in Arusha of Gishwati became permanent, more trees were cut down for construction purposes because they were sheltered under plastic sheeting, and for cultivation.

Spontaneous occupation of Gishwati forest has led to deforestation and consequently to environmental degradation (biodiversity loss, soil erosion, ad disturbed hydrology) hence disruption in socio-economic conditions of local populations.

Human have affected every part of the globe. over the past decades, billions of ha of forests, woodlands and grasslands have been converted to croplands or permanent pasture, but overharvesting, erosion, pollutions and other forms of degradation also have turned large area into desert or useless scrub.

The livelihoods of the people around Gishwati forest depends on it for firewood, charcoal, medicines, and food are increasingly under pressure from unsustainable use resulting in its degradation as well as decline in ecosystem goods and services that restrict to economic development(REMA 2009).

2.2.Forest degradation

Deforestation and forest degradation are the biggest threats to forests worldwide. Deforestation occurs when forests are converted to non-forest uses, such as agriculture and road construction. Forest degradation occurs when forest ecosystems lose their capacity to provide important goods and services to people and nature. Over half of the tropical forests worldwide have been destroyed since the 1960s, and every second, more than one hectare of tropical forests is destroyed or drastically degraded. Forest degradation is a process in which the biological wealth of a forest area is permanently diminished by some factor or by a combination of factors. "This does not involve a reduction of the forest area, but rather a

quality decrease in its condition. "The forest is still there, but with fewer trees, or less species of trees, plants or animals, or some of them affected. This degradation makes the forest less valuable and may lead to deforestation. Forest degradation is a type of the more general issue of land degradation**.** Deforestation and forest degradation continue to take place at alarming rates, which contributes significantly to the ongoing loss of biodiversity.

2.2.1.Causes of forest degradation

a. Climate Change: Changes in world's climate due to average atmospheric temperatures are a leading cause of forest degradation. These changes in climate cause droughts and extremely dry or cold periods which create undesirable environmental conditions for tree covers to thrive.

Prolonged dry conditions and droughts can equally dry out the water systems running through the forests thereby reducing the number of trees and species in such areas. Climate change causes extreme change in forest ecosystems. In most cases, animals are forced to migrate to other regions, reducing the quality of forest ecosystems.

b. Forest Fires: such as the ones that commonly happen in dry tropical forests are a major cause of forest degradation. Forests fires may arise on the account of natural, accidental, and human causes. Whenever forest fires are experienced, thousands of trees and vegetation cover are destroyed. Almost every year, forests fires are witnessed across different forest region on earth which persistently affects the economy and biodiversity.

c. Air pollution: is a substantial causal factor for forest degradation. Pollution of the air by harmful gases and emissions leads to atmospheric acidification and acid rain that causes damage to trees and vegetation cover.

d. Forest Fragmentation: Fragmentation can also contribute to forest degradation. Fragmentation refers to separation of large forest areas into smaller pieces. It mainly occurs due to natural causes such as tectonic movements or flooding. Fragmentation destroys healthy ecosystems since large forest animals mostly thrives in large forest regions. Fragmentation also changes the food chain interactions and the mutual relationships within the forest physical environments.

2.2.2.Effects of forest degradation

a. **Loss of biodiversity:** The most significant effect of forest degradation is loss of habitat leading to species loss. Forests are among the most biologically diverse ecosystems on the planet. Over half of all species live in rainforests, which are subject to the greatest deforestation pressures. Biodiversity loss can occur during selective logging as well, as individual species may be intolerant to loss of a particular tree type or to the presence of logging operations. Species loss within forests can spread to surrounding ecosystems.
b. **Disruption of the water cycle:** Evapotranspiration refers to the water that evaporates from the forest back to the atmosphere, increasing rainfall across nearby ecosystems. Loss of forest disrupts this cycle, resulting in less rainfall and causing drier conditions over broad surrounding areas, sometimes leading to drought. Forests also capture(Baird 2001) moisture from rainfall, Loss of forests often results in increased flooding and erosion of sediment into rivers, disrupting river ecosystems.
c. **Soil erosion** Forests contain particularly rich soil that has received organic material over extended periods of time. When forest is destroyed, the soil is exposed to the sun, which causes it to lose nutrients. During heavy rains, the dry soil is washed away due to lack of root structures in the ground. Once topsoil is lost in an area, it can be very difficult to re-establish forest or use the land for other productive purposes.
d. **Global warming** Deforestation is a primary cause of human-caused carbon dioxide emissions leading to global warming. All forests contain large amounts of carbon. When they are destroyed, the burning or decomposition of forest releases this carbon into the atmosphere in the form of carbon dioxide. Carbon dioxide is a greenhouse gas, absorbing solar heat within the atmosphere. Therefore, higher concentrations of atmospheric carbon dioxide led to a warmer climate. Global warming threatens ecosystems and biodiversity worldwide (Larry 2006).

2.3. Population control measures

The world population has been growing extremely since the 1960's to reach close to 7 billion todays; again, future medium projections show that the world will pass 8 billion in 2023, 9 billion in 2041 and 10 billion after 2081 given current birth and death patterns continue to prevail. It is this pattern coupled with its negative impacts that has led to many concluding that the world is overpopulated (Affairs 2011). The United Nations held a number of conferences to discuss the means to control world population growth. The most influential

conference was the 1994 International Conference on Population and Development (ICPD) held in Cairo; the conference reached an agreement on the urgent need to control global population growth.

Family planning use as one of the critical approaches initiated by United Nations member states as a way of regulating world population. Different member states were urged to promote and make access to family planning a priority for the purpose of regulating world population growth (Maluleke 2011). These family planning methods work by physically preventing sperm from entering the female reproductive system. These devices include Male condom. Female condom, Spermicides, Diaphragm, Cervical cap and Contraceptive sponge. Abstinence is the voluntary avoiding from sexual intercourse. This method is regarded as the only family planning method that is 100% effective in the prevention of both pregnancy and sexually transmitted diseases.

The fertility awareness method which is often called “natural family planning”. Apart from abstinence and withdrawal method, this is the method that does not rely on devices or medication to prevent pregnancy. The natural family planning method uses the natural functions of the female body and menstrual cycle to calculate ovulation. It requires abstinence from sexual intercourse during the ovulation period (Maluleke 2011). Demographers regard withdrawal and abstinence as traditional methods while the other methods are regarded as modern methods of contraception.

2.4. Suitable forest conservation strategies

Forest clearance and degradation has been widely recognized and many Governments have implemented forestry legislation and programmes that aim at conservation and management forests. (Lusweti 2011) noted that increasing public awareness is one of the most important steps in biodiversity conservation and this can be achieved through educational programmes, incentive programmes, and voluntary programmes. Rwanda has made significant progress in putting in place the proposed measures for biodiversity use and conservation. In addition, Rwanda also participates in the international programmes. (Rosendal 2000).

Another solution has been to designate forests as protected areas. Some 11.7 per cent of African forests have protected area status(FAO 2001a). While the establishment of protected areas has increased the availability and quality of information on forest resources, promoted

public awareness and created refuges for endangered species but these areas will meet their objectives only if protection measures are enforced. According to (Maathai 2005) in(Ongugo 1998), a sustainable management of forest resources will only be possible if we practice good governance of the forest resources which calls for respect for rule of law, respect for human rights, willingness to give space and voice of the weak and the more vulnerable in our society.

Rwandan government values the role of the forestry sector in the livelihoods of the population and economic development, it established policies which protect forest resources, and involved non-government organizations (NGOs), but it has not yet reached its full economic and ecological potential, because of local community who continue to encroach the forest.

1. Enforcing laws and regulations concerning about conservation and protection of forests.
2. Control over Forest Fire
3. Reforestation and Afforestation
4. Check over Forest Clearance for Agricultural, Settlement, cattle grazing
5. Protection of Forests
6. Proper Utilization of Forest and Forests Products

2.5 Relationship between population growth and forest degradation

Rapid population growth leads resource degradation, including deforestation, overgrazing, soil erosion, soil nutrient depletion, and other problems (Scherr and Hazell 1994). As population density increases, the supply of people who clear trees increase (wilson 1987, southgate 1988)) and the demand for products from forest grows too. As population continue to increase, a larger forest area become deforested and leads to biodiversity loss.

In addition to these forest changes, both the number of producers who use degrading agricultural or grazing practices increased(repetto 1986, Waswa 2012) .Humans have affected tropical rainforests in many ways, particularly through logging, agriculture and several studies have examined that there are long-term effects of logging on forest. ;(struhsaker 1997) .Population growth removed trees from particular areas in order to make various wood products, to clear land for new buildings or roads, for creating new farming or grazing land. It

can also occur as a result of natural disasters or accidental fires(x-Giam 2017). Deforestation can lead to a direct loss of wildlife habitat as well as a general degradation of their habitat. ... Wildlife habitats become fragmented, where native species must live on remaining habitat islands that are surrounded by disturbed land that is being used for agriculture and other uses.

2.6.Socio-economic values of Gishwati forest

Gishwati forest provides livelihood for thousands of Rwandans who live around Gishwati. The forest helps to maintain the topsoil's fertility and keeps it from eroding away helps to sustain the productivity of the land. Communities obtain many wood and other products from the forest. Timber, rope, bamboo, and other traditionally used forest plants are still important to people for weaving, medicines, building and more, and need to be harvested sustainably to protect the forest's integrity. In addition, these remaining forest fragments are particularly important for their cultural value to the neighboring communities. The natural forest has been exploited by humans for as long as they have existed. Over the years, people living in surrounding villages have often encroached and grazed their cattle. In the future the forest may generate even more benefits to the national and local economies through the development of tourism. The forested landscapes and the species and habitats create substantial potential for this economic activity

2.7.Conservation challenges of Gishwati Forest Reserve

Gishwati Forest Reserve (GFR) has a long history of deforestation which reduced its area from a record of 100,000 ha to as low as 600 ha. Even if the reforestation efforts increased the forest reserve to 1,484 ha from 2008 to 2011, Population pressure and heavy dependence on agriculture and natural resources leads to many challenges to Gishwati Forest Reserve. GFR continues to meet challenges of human pressure in search of minerals, poaching, firewood collection, animal grazing, charcoal making and timber harvesting. Such pressures are likely to continue impacting on the wildlife species. The challenges can be mitigated by:

- ✓ Establish a community participation approach that allow equitable sharing of conservation costs and benefits through Conservation Agreements.
- ✓ Build business base for income-generating to improve local livelihoods.
- ✓ Establish a buffer zone around Gishwati Forest Reserve.

2.8.Management of Gishwati forest

2.8.1.The PAFOR Project

Gishwati Forest was first established as a forest Reserve in 1933. A combination of factors including encroachment by human populations, deforestation and conversion forest land uses has seen the forest area decline over the years. In 2002, the fragmented forest was covering only 600 hectares. there has been growing interest to restore Gishwati Forest has been growing since 2002, when floods and landslides killed people in this area. Several projects have been initiated in the area in support of reforestation and restoration using such techniques as agro-forestry techniques, radical terracing, progressive terracing. As a result of these, Gishwati Forest Reserve is under different stages of regeneration. From 2005 to 2008, PAFOR increased the size of the Gishwati Forest Reserve from 600 hectares to 886 hectares

2.8.2.Gishwati Area Conservation Program (GACP)

From 2008 to 2012 a restoration project, the Gishwati Area Conservation Program, was started to extend the area of Gishwati through natural regeneration. This program was supported by the Great Ape Trust in collaboration with Rwanda Environment Management Authority (REMA where from 2008 to 2009 GACP extended this forest up to 1,484 ha.

2.8.3.The Forest of Hope Association (FHA)

FHA is a National Rwandan Non-Government Organization (NGO) focusing on the conservation of the GFR. Established in January 2012, FHA builds on the GACP, an International NGO that worked on conservation of the Gishwati Forest Reserve from 2008 through 2011. FHA took over the work of the GACP and is taking the GACP mission forward by continuing engaging local communities in conservation of the GFR. The Mission of FHA is: “Engaging local communities in conservation and restoration of the GFR, to build a sense of ownership and responsibility for its management”. FHA’s main activities are conservation education, mitigating crop raiding, improving local livelihoods and facilitating research on the biodiversity of the GFR.

2.9.Research gap

1. Lack of incentives to the public around the study area so that they cannot rely on forest products
2. Weak laws and regulations about population control because the research shows how increasing population affects the forests worldwide
3. There is a shortage of training programs for forest conservation and management activities

CHAPTER THREE. RESEARCH METHODOLOGY

3.0. Introduction

This chapter presents the methods and procedures used by the researcher in collecting data for this study as well as methods for its analysis. The research design, description of study area, data processing, data collection methods, data analysis, Accuracy of data and limitations of the study.

3.1. Description of study area

The Gishwati Forest Reserve (GFR) expanding on about 15.70 km² (1570 ha) is a secondary mountain rainforest fragment located just south of Volcanoes National Park in western Rwanda, within the altitudes 2000 – 3000 meters above sea level (Fig 3.1) (https://www.cepf.net/sites/default/files/guidebook-gishwati-mukura-national-park.pdf). It is part of the Congo-Nile divide forest complex that includes Mukura Forest Reserve, Nyungwe National Park in Rwanda and the contiguous Kibira National Park in Burundi. The GFR is located Nyabihu, Ngororero and Rutsiro District, and neighbors four sectors within the district: Kigeyo, Ruhango, Nyabirasi and Mushonyi. The Gishwati Forest Reserve is located in one of the most densely populated areas of Rwanda, where unsustainable agricultural practices have led to reduced crop yields, and forest-adjacent communities have been driven to seek out alternative livelihoods. This has led to increasing pressure on the natural forests in the form of growing encroachment, poaching and other types of illegal resource exploitation(Elizabeth 2009) *"Rwanda State of Environment.* "Conservation of Chimpanzees in the Congo Nile divide forests of Rwanda and Burundi. This Forest is under different stages of regeneration. From 2005 to 2008, PAFOR increased the size of the Gishwati Natural Forest from 600 hectares to 886 hectares. From 2008 to 2009, Gishwati Area Conservation Program (GACP) extended this forest up to 1,484 hectares. The 336 hectares added in 2008 have been reforested from late 2009 to early 2010 and the 262 hectares added in 2009 to stabilize steep hillsides in an area called Kinyenkanda that has been plagued by landslides and severe erosion into the Sebeya River, are under natural regeneration.

Gishwati Natural Forest has a history of deforestation extending over the past 50 years, in part because of advised large-scale cattle ranching schemes, resettlement of refugees after the genocide, inefficient small-plot farming, free-grazing of cattle, and establishment of

plantations of non-native trees. As a result, the area is plagued with flooding, landslides, erosion, decreased soil fertility, decreased water quality, and heavy river siltation, all of which aggravate local poverty. In 1970s, Gishwati forest was 28,000 hectares. In 2002, the remnant forest was only 600 hectares. The interest to restore Gishwati Natural Forest has been growing since 2002 when floods and landslides killed people in this area. The interventions include restoration activities of the Government Reforestation Project, Projet d'appui a la Reforestation au Rwanda (PAFOR) from 2005 to 2008 and the ones of the Great Ape Trust/GACP from 2008 to 2011.

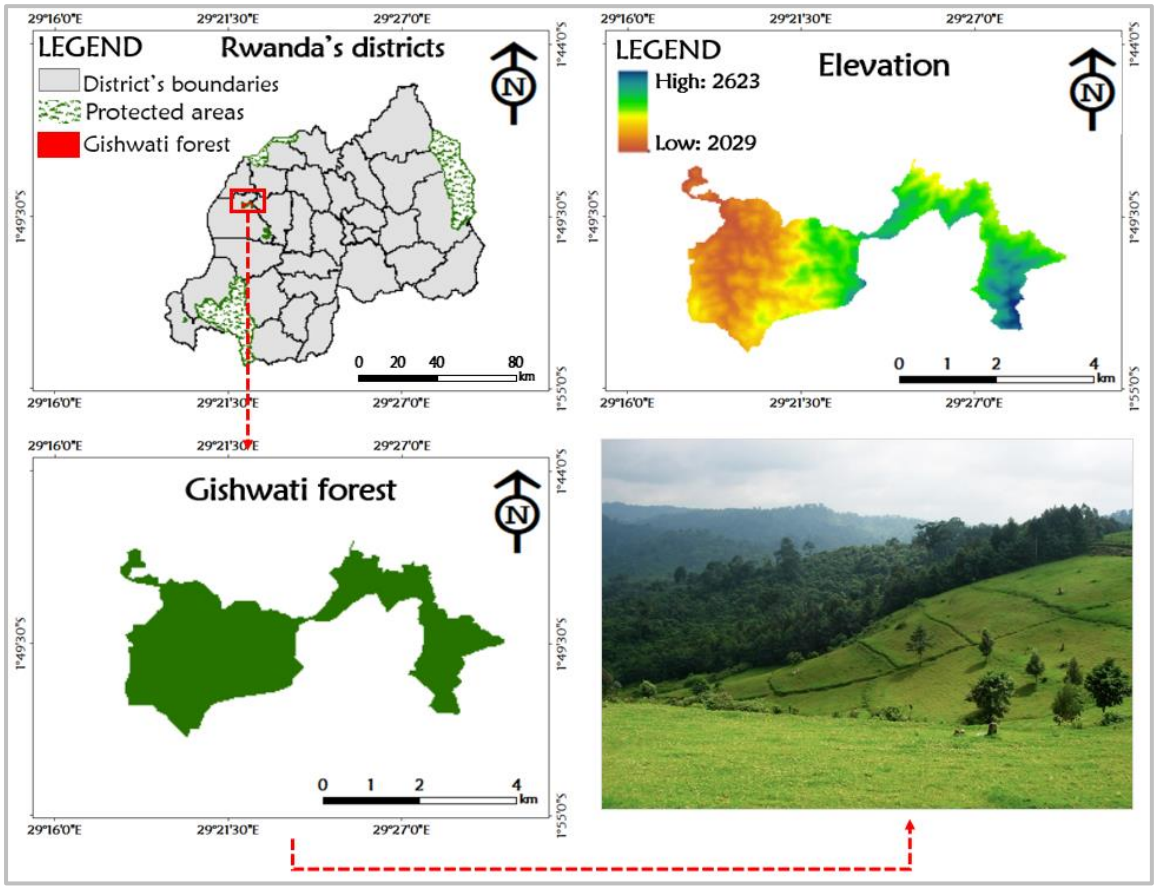


Figure 3. 1.Study area map and its location on national scale. source: author's mapping in ArcMap ArcGIS 10.8

3.2.Research Design

A research design is defined as a plan outlining the way information is being gathered for an assessment that includes identifying data collection methods, how information will be organized (Bryman, 1998). This research was based on secondary datasets and their analysis involved the usage of Remote sensing techniques and Geographic Information System (GIS)

for mapping. The research mainly consisted of using secondary data which related to the data on population growth as well as satellite imageries for land use land cover change mapping of Gishwati forest.

3.3.Data collection and processing

The data collection process for analyzing the impact of population growth on forest degradation in Gishwati Forest involved multiple sources, each providing critical inputs for the research. Statistical population data were obtained from UN-Worldometer (https://www.worldometers.info/world-population/rwanda-population/) a platform that elaborates on the latest United Nations demographic data. This resource provided comprehensive population statistics, including yearly population counts and growth rates, which are essential for understanding demographic trends in Rwanda. The data was crucial for assessing the relationship between population dynamics and land use changes, as it allows for the calculation of population density and trends over the timeframe of the study. The specific focus was on the population dynamics relevant to the Gishwati region, facilitating an in-depth analysis of how human activities correlate with forest health.

Vector shapefiles were sourced from DIVA-GIS (www.diva-gis.org), providing essential geographic information at a national scale. These shapefiles are instrumental for spatial analysis, offering delineated boundaries for Gishwati Forest and surrounding regions. This geographic context allowed for precise mapping and overlay analysis in conjunction with satellite imagery and population data. Utilizing these shapefiles ensures that the spatial analysis is rooted in accurate geospatial data, enhancing the integrity of the research results.

Multi-spectral satellite images from the Landsat TM, ETM, and OLI sensors were acquired through the Earth Explorer platform operated by the United States Geological Survey (USGS) (https://earthexplorer.usgs.gov/). These images had a spatial resolution of 30 meters and were collected at various intervals (1990, 2000, 2010, and 2020) to facilitate change detection analysis over the three decades. The Landsat data provides critical insights into land use and land cover changes, particularly in assessing forest cover and degradation trends in Gishwati Forest. This satellite-based information forms the backbone of the remote sensing analysis, enabling detailed monitoring of environmental changes.

High-resolution images from Google Earth Pro were also utilized, acquired online to complement the Landsat data. With a resolution of 15 meters, these images serve as valuable reference points for validating the classifications derived from the Landsat imagery. The adaptability and detail provided by Google Earth imagery enhance the overall analysis, allowing for accurate interpretation of land cover changes and serving as a reliable ground truth reference during the analysis phase.

Table3. 1.shape file

Dataset	Type	Source	Resolution
Population data	Statistical	UN-Worldmeter (https://www.worldometers.info/world-population/rwanda-population/)	-
Shapefiles	Vector	DIVA-GIS (www.diva-gis.org)	National scale
Landsat TM/ETM/OLI	Raster	Earth exploration (USGS) https://earthexplorer.usgs.gov/	30 m
Google earth image	Raster	Google earth pro	

3.4.Data Analysis

The analysis of the impact of population growth on forest degradation in Gishwati Forest followed a systematic and integrated methodology. This process begins with the careful preparation of data, crucial for ensuring the reliability and accuracy of the results. The various data sources were meticulously gathered, including shapefiles that define the geographic boundaries of Gishwati Forest and surrounding areas, comprehensive population datasets that provide demographic insights, and satellite imagery from the Landsat series for the specified years. Google Earth images serve as a valuable resource for high-resolution reference and validation of satellite classifications, enhancing the overall analytical robustness.

The Landsat images undergone atmospheric correction to eliminate distortions caused by the atmosphere, employing the Landsat Surface Reflectance product to improve the fidelity of the images. Subsequent georeferencing ensured all datasets, including shapefiles and population information, are aligned within the same coordinate system. This alignment was critical for accurate spatial analysis. The next stage involved land use and land cover classification. The supervised classification techniques were applied to the Landsat images,

distinguishing between forest cover and other land uses. Training areas were established based on known land cover types, which enhanced the accuracy of the classifications. Validation of these classifications was then conducted by cross-referencing the results with Google Earth imagery or existing field data, allowing for adjustments to the classification model as necessary.

After classifying the images, a change detection analysis was performed. This involved comparing the classified land cover maps from the years 1990, 2000, 2010, and 2020 to quantify changes in forest cover. By assessing the area of forest cover and determining the extent of degradation over time, critical metrics was calculated, including rates of deforestation. The results of this analysis provided insight into how the forest landscape has transformed over the three decades. Concurrently, population growth was analyzed by creating population trend using the gathered census data. A crucial aspect of the analysis was the examination of the spatial correlation between population density and forest cover changes.

Geographic Information System (GIS) tools facilitated this analysis, allowing for spatial analysis and statistical methods to gauge the degree of association between population growth and forest degradation. This step provides quantitative insights into how demographic shifts may influence forest health. Integrating these datasets was achieved through overlay analysis; this visualization highlights areas where population growth intersects with significant forest degradation, making it easier to identify critical zones of concern. The findings from this analysis were synthesized into visual representations, including thematic maps, graphs, and charts. These representations not only summarize the data findings but also illustrate complex relationships between population dynamics and forest degradation in a comprehensible manner.

3.5.Research reliability and validity

Reliability is about the accuracy of data**.** In this research, the methods which were used by the researcher were explained in order to get accurate data basing to the targeted objectives. The resulting LULC maps were validated using an original source (Google earth image) and from observation by the researcher doing a field visit. The researcher believes that the sources of data used in this study are trustworthy and can be used by other researchers interested in the

same field of study. These data were collected, analyzed and interpreted with reference to recent experts.

3.6.Limitations of the study

The limitations of the study are those characteristics of methodology that impacted or influenced the application or interpretation of the results of the study**.** When the researcher was conducting the research, there are some barriers that occurred. Some of those barriers among others are:

Time was also big obstacle and it was difficult to do the research while conducting my internship. To overcome this obstacle, the research worked day and night. Finally, expected and received funds to conduct the research was quasi-insufficient to enable the researcher covering all costs required in conducting this research. We cannot ignore the constraint related to the data quality. It is found that, in many cases, the desired satellite imageries will not be available or even if available, be highly contaminated by clouds that limit its use. Under these circumstances, these cloudy scenes were replaced by the existing better-quality images taken during the same year or the closest months to the initially targeted scenes

CHAP FOUR: DESIGN SPECIFICATION, RESULT AND DISCUSSION

4.0.Introduction

This chapter intends to present the results and discuss respectively the findings according to the objectives of the study; which are to: assess the trend of population growth in the study area, analyse the extent at which Gishwati forest is being degraded and discuss the impacts of population growth on forest degradation**.**

4.1.Trend of population growth in the study area

In Rwanda, the total population is approximately 13,730,334 as of Tuesday, December 6, 2022, based on Worldometer elaboration of the latest United Nations data. The latter is projected to reach 23,048,005 by the vision 2050 (https://www.worldometers.info/world-population/rwanda-population/). This population is equivalent to 0.17% of the total world population and ranked number 76 in the list of countries (and dependencies) by population. Over a decade (from the population census carried out in 2012 to date), the population has increased by over 3 million. The population of Rwanda is still largely rural, with 83% living in rural areas. There are some clear differences among the provinces. Rwanda's rate of population growth is greater than that of the global average but similar to that of neighboring countries. The high population of Rwanda is the main driver to land pressure especially land use land cover (LULC) which consequently results in the environmental disasters and encroachment on the fragile ecosystem (Piller 2016, Nsengiyumva, Luo et al. 2018).

Talking of Gishwati forest, it is found in four Sectors of Rutsiro district, which are Kigeyo, Ruhango, Nyabirasi and Mushonyi. The total number of human populations living around the forest was counted to be approximately 1,381,730 inhabitants in 2020 with the density of around 483.1 people per km^2 .

Following the considered periods of analysis, it is clear that the study area has undergone great population growth from 1990 – 2020 as depicted in Fig 4.1.

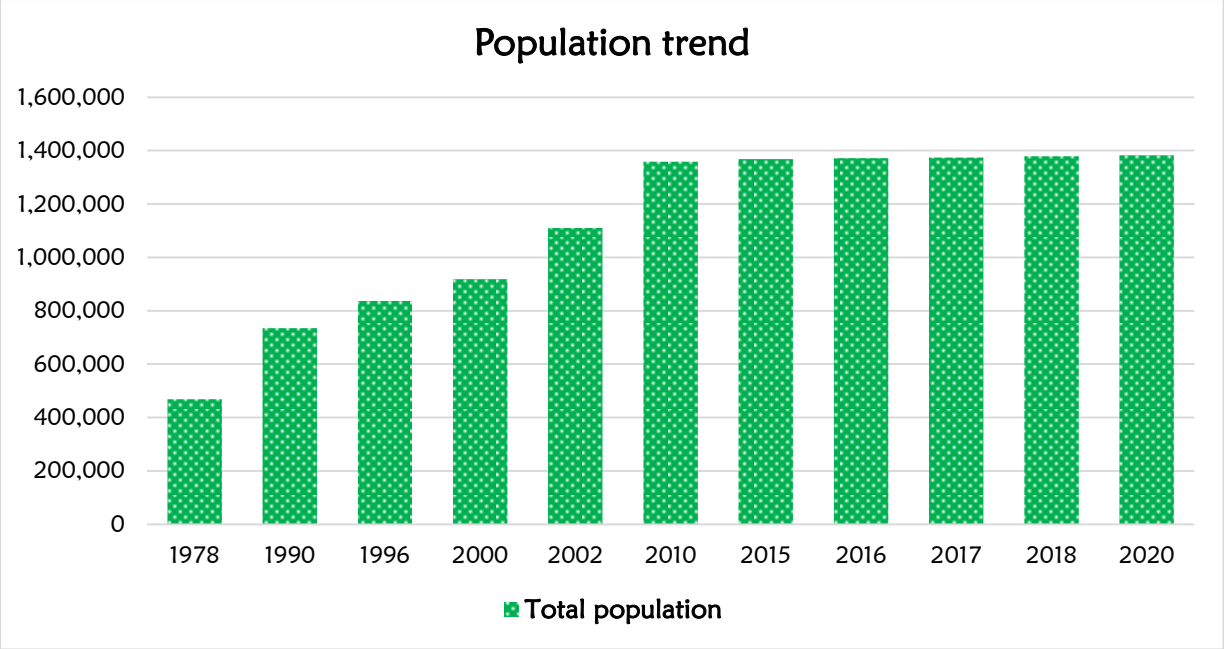


Figure 4. 1.Population trend of the study area considering the study period (1990, 2000, 2010, 2020)

On the other hand, Rwanda is a geographically small country with one of the highest population densities in sub-Saharan Africa. Despite a high population density (Table 4.1), the dominant pattern is one of extreme dispersal. Almost three-fourths of the population is rural and lives in nuclear family.

Table4. 1.Statistics on population growth and population density

Year	Total population	Area	Pop density
1978	468,882	2,049.3m^2	228.8
1990	734,654	2,486.1m^2	295.5
1996	836874	2,602.2m^2	321.6
2000	918650	2,799.0m^2	328.2
2002	1,109,631	2,647.6m^2	419.1
2010	1,358,745	3,177.6m^2	427.6
2015	1,367,927	2,968.5m^2	460.8
2016	1,371,002	2,898.5m^2	473
2018	1,378,449	2,853.3m^2	483.1
2020	1,381,730	2.860.1m^2	483.1

4.2.The extent at which Gishwati forest has been degraded through land use land cover change detection

Worldwide, forest loss is more common than forest gain, although the characteristics and direction of change differ depending on the region and the driving forces (Drummond and Loveland 2010). Forest is change in response to a variety of pressures, with implications for biodiversity, run-off, carbon storage, ecosystem values, agriculture, and the broader economy (Gurgel, Reilly et al. 2021). Drivers of land use changes include several demand and supply forces, such as increasing population and consumption together with economic and income growth. Considering this study:

From 1990 to 2020, the Gishwati landscapes cover has changed with a domination of four main land cover types namely forestland, cropland and a very small part of water in 2000.

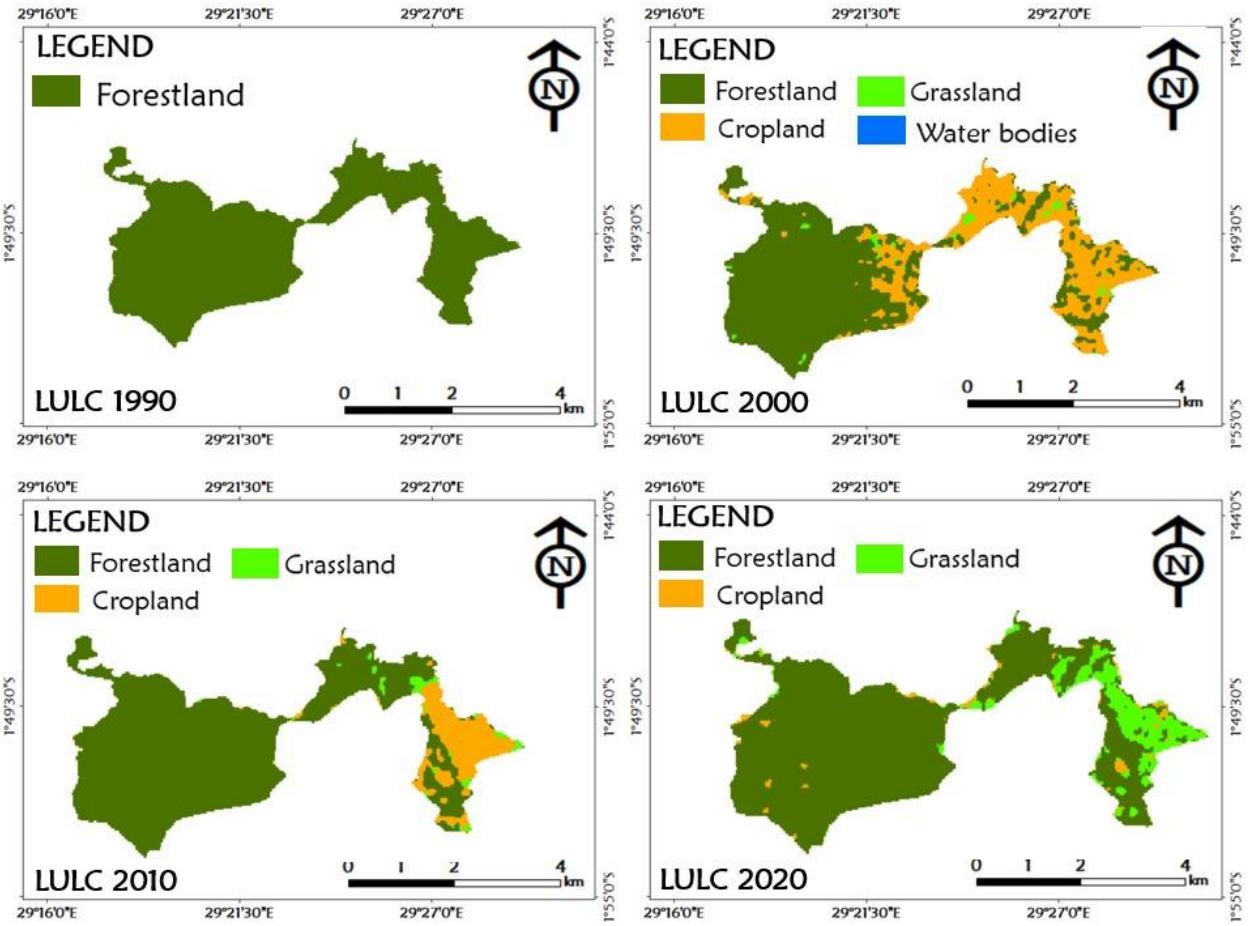


Figure 4. 2.Gishwati land cover change (1990-2020)

In 1990, The majority of the area was covered in forests. Since the entire region is represented in dark green, forests predominated as the predominant land cover. This indicates that the area's native vegetation was preserved while being mostly untouched by human activity.
There is little to no visible grassland or cropland at this point, indicating that there hasn't been much of a change in land use for agriculture or other uses. The ecosystem of the original forest was mainly preserved.

By 2000, significant changes begin to appear. Large areas of the forest, especially in the eastern part of the region, have been converted into cropland (marked in orange). This transformation indicates the beginning of deforestation, likely driven by agricultural expansion. Small blue patches representing water bodies become visible for the first time. This could be due to the creation of artificial reservoirs, rivers or other water-related developments accompanying agricultural expansion. The continuous forest cover starts to break up, with noticeable fragmentation in various parts of the region, especially near the areas being converted to cropland.

By 2010, the process of land conversion has intensified. The southeastern part of the region shows even more extensive cropland coverage. The orange areas on the map have expanded significantly compared to 2000, indicating ongoing deforestation and land conversion.

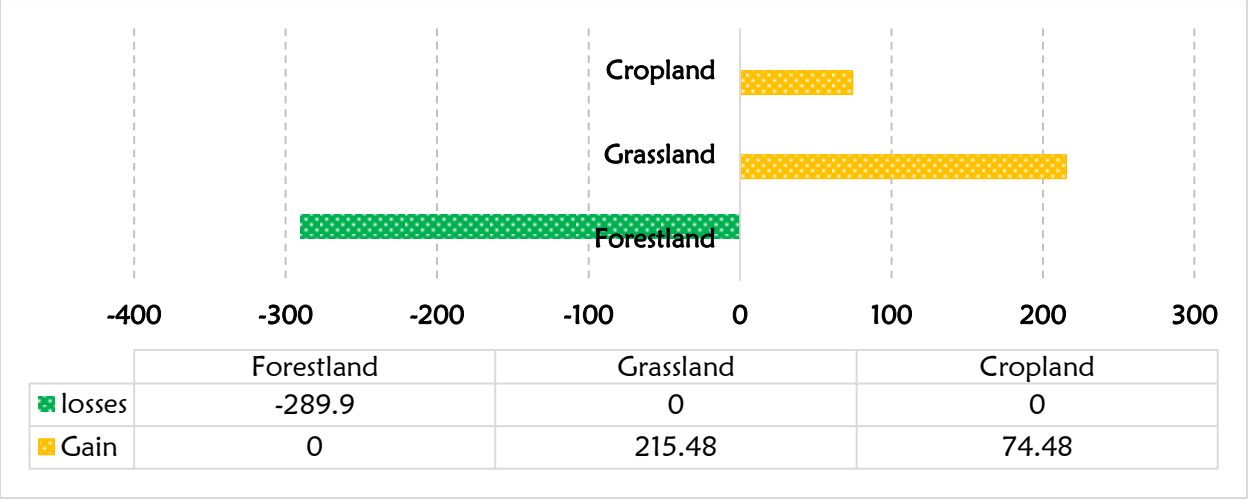
The remaining forested areas are shrinking, with the forestland becoming more scattered and less contiguous. This could indicate increased deforestation rates, possibly for agricultural or other land use purposes. At this point, grassland is still not a prominent feature, suggesting that the conversion of forestland has been mainly towards cropland rather than less intensively managed grassland areas.

In 2020, grassland (marked in light green) becomes more prominent, particularly in the northeastern part of the region. This could be a sign of either land degradation (where land transitions from forest or cropland to grassland due to loss of fertility or other factors) or a shift towards less intensive land use. Grassland areas may also develop naturally in abandoned agricultural areas. Cropland continues to expand, though not as rapidly as between 2000 and 2010. The southeastern part of the region still shows significant cropland areas, indicating that agriculture remains a dominant land use.

The forestland has continued to decline, with fewer and more isolated patches of forest remaining. This highlights the ongoing deforestation process, which may be linked to various factors such as logging, agriculture, or infrastructure development. The water bodies identified in 2000 remain visible, indicating that these features have become a stable part of the landscape, possibly supporting agricultural irrigation or serving other water-related functions.

In conclusion, the LULC maps show a region that has seen a considerable change in land use over time, with new water bodies emerging and forestland giving way to crops and grassland. These changes have significant effects on the environment and sustainability of the area and are probably caused by human activity, especially agriculture.

The forestland in 1990 was ever green without any disturbance by human population but in 2000 the forestland has declined at the expense of growing cropland which went in parallel with the growing population. During the period 1990–2000, about 558.5 ha (35.57%) of forest cover were lost. Whilst during this period, 496.5 ha of cropland and 60 ha of grassland areas emerged (Table 4.2). This signifies that there is a big part of forest cover which was converted into cropland. From 2000-2010, the forestland and grassland areas increased by 260.76 ha (25.7%) and 10.85 ha (18.3%), respectively while the cropland decreased by 269.52 ha (54.3%). From 2010-2020, forestland and grassland increased by 7.84 ha (0.62%) and 144.63 ha (204.1%), respectively. It is understandable that these forests and grassland conversions to agriculture were related to the rapidly growing population, increasing from 295.5 people/km^2 in 1990 to 328.2 people/km^2 in 2000 (Table 4.1), along with the fact that today around 80% of the Rwandan population depend on subsistence agriculture for their livelihood (Karamage, Zhang et al. 2017). In 2010, the forestland increased compared to the year 2000 with the declining status of cropland and grassland. This condition can be justified by the stated restoration projects that emerged at that particular time such as the Forest of Hope Association (FHA) through raising awareness in local community on the importance of forest. In 2020, the forestland and grassland continued to increase with an extreme decline in cropland compared with the year 2010.



	Forestland	Grassland	Cropland
losses	-289.9	0	0
Gain	0	215.48	74.48

Figure 4. 3. The gain and losses from 2000 – 2020 (in ha)

From 1990-2000, the Gishwati lost about 289.9 ha of forest area with a gain in grassland and cropland of about 215.48 ha and 74.48 ha, respectively (Fig 4.3).

Cattle grazing is the most frequent illegal activity explaining the increased area of grassland. Shortly, the decreases of the cropland have compensated all the increase of forest and grassland. This is more beneficial to biodiversity because among the studied land cover types, cropland play a big role in fauna and flora disturbance more than others by clearing the above ground vegetation. This is also because the Rwandan Government passed a law to create a new national park combining Mukura and Gishwati forests. If the expansion of residential and farming area is not managed, it will certainly diminish forest cover in many locales of the area.

Table4. 2.LULC change from 1990 -2020 with 10 years' interval

Area in hectares					
Classes	1990	2000	2010	2020	Change
Forestland	1570	1011.5	1272.26	1280.1	-289.90
Grassland	0	60	70.85	215.48	215.48
Cropland	0	496.5	226.98	74.48	74.48
Water bodies	0	2	0	0	0.00
Total	1570	1570	1570	1570	

LULC is under a continuous conversion mainly because of societal development and natural causes. To understand the contemporary dynamics of forest cover and land use, we observed

land conversions that cause forest loss or gain across four-time intervals. Our results in Gishwati, which are on the basis of contemporary LULC change analysis between 1990 and 2020, indicate that the historical trend of conversion from forest cover to agriculture did not really continue at a large extent since 2000, but the remaining agricultural activities and the related action can or are still causing impacts on climate, biodiversity, hydrological cycles, ecosystems, and many other processes.

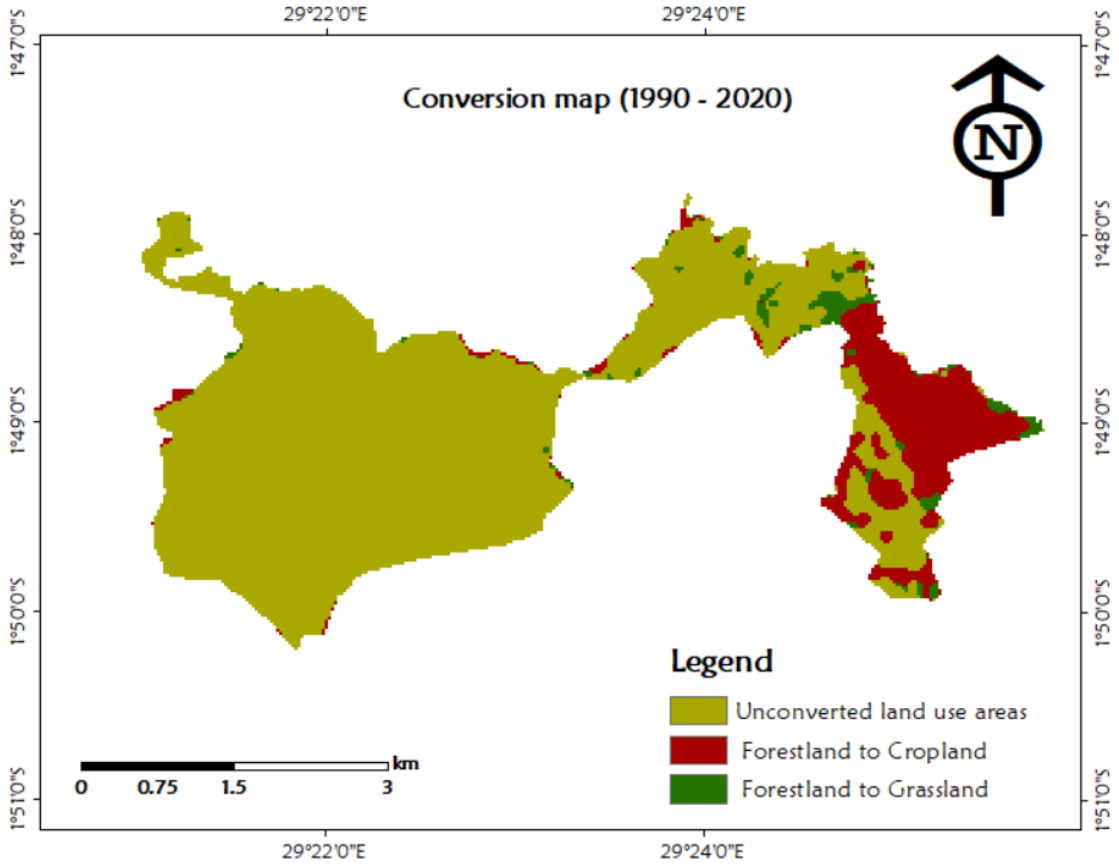


Figure 4. 4.Major land cover/use conversions in Rwanda (1990–2020)

However, In Rwanda, some programmes have begun with the aim of restoring degraded forest and forming associations related to regeneration of Gishwati. The project is such us the "Projet d'appui a la Reforestation au Rwanda (PAFOR), Great Ape Trust/Gishwati Area Conservation Program (GACP)". Comparing the forest status from 1990 to 2020, The Rwandan government should be congratulated following its invested efforts put in Gishwati for its restoration and conservation leading to its nomination as a national park. The complete restoration of the Gishwati forest will bring a set of ecosystem services such as sequestrate the emitted carbon dioxide, water purification, biodiversity conservation and even food production for a rapidly growing population among others.

4.2. The impacts of population growth on forest change

Many researchers (Shukla, Ojha et al. 2018, Genet 2020) indicated that LULC change and population growth have a strong relationship. As population increases, the need for cultivated land, grazing land, fuel wood, settlement areas also increase to meet the growing demand for food and energy, and livestock. Population growth and density are indirect factors for LULC conversion through the growing needs for additional lands for farming and grazing as well as demands for tree products (fuel and construction wood). In this regard, recent studies (Ouedraogo 2010, Lambin and Meyfroidt 2011) concluded that land cover conversions due to demographic pressure are more serious largely in tropical regions such as Latino America, Africa and Southeast Asia. Population pressure has both positive and negative impacts on the environment in a given area. Since environment and population are closely interrelated, they cannot be studied separately. Population and environment have a complicated relationship. More people mean more food, which consequently result into either expansion of agricultural areas into new lands, or use of existing agricultural land more intensively. Rapid population growth exerts pressure on the existing land resources through increasing the demand for food, wood for fuel and construction purposes, and other necessities (Pimental, Huang et al. 2015).

During the last two decades, agricultural expansion, logging, development and other human activities caused deforestation. An overview of studies conducted in 1990s reveal a strong relationship between population growth and deforestation mostly in developing countries (Mapulanga and Naito 2018)**.** Humans are cutting and burning down forests. Over 80% of the world's forests have been destroyed. Humans are destroying forests because the human population is increasing dramatically and we need more resources. Some of the reasons we are cutting down forests include land (we are needing more land because the human population is increasing and humans are needing more land to live), paper, furniture, roads (we need more roads because we are cutting down forests so people can live there and they need a way to move around so we need to make roads), and farming (we are cutting down forests for farming because the human population is growing and we are needing more food).

There are also many reasons we need to save them, these include carbon storage, fuel wood, and charcoal (we use coal for electricity). We might be wondering how we can save forests. Some techniques among others are such as the restoration of damaged ecosystems by practicing afforestation and re-afforestation. Encourage people to live in a way that doesn't hurt the environment. Establish parks to protect rainforests and wildlife. Support companies

that operate in ways that minimize damage to the environment. Population growth has contribution immensely to resources degradation especially as it affects the forest ecosystem. due to population growth and human encroachment in the forest ecosystem. However, there is urgent need for the various stakeholders in environmental resource management to provide a mechanism that would prevent the forest ecosystem from further depletion in the area.

The impact of demographic changes on forests and the environment is often discussed in terms of biological carrying capacity, i.e., the maximum number of individuals that a resource can sustain. the declining of forest accompanied by variety of other environmental problems is caused by agricultural expansion and wood gathering. The major factors contributing to deforestation are poverty, low level of income and population growth. The increase in demand for food leads to a decrease in natural resources especially forest resources when individuals encroach on them in search for more for cultivation, and yet these forest resources are needed for a nation to survive. There is growing evidence that human activities harm the environment and as the world's population grows, improving living standards without destroying the environment is a global challenge.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.0 INTRODUCTION

A summary of major findings of the study entitled "Assessment of the impact of population growth on forest degradation, a case study of Gishwati forest (1990-2020) is developed within this chapter. Later, a general conclusion is drawn along with recommendations based on the findings.

5.1 Summary of findings

The first objective was about the trend of population growth in the study area, in Rwanda, the total population is approximately 13,730,334 as of Tuesday, December 6, 2022, based on Worldometer elaboration of the latest United Nations data. The latter is projected to reach 23,048,005 by the vision 2050, our findings revealed that Rwanda is a geographically small country with one of the highest population densities in sub-Saharan Africa. The total number of human populations living around the forest was counted to be approximately 1,381,730 inhabitants in 2020 with the density of around 483.1 people per km^2 (National Institute of Statistics Rwanda, 2020). Following the considered periods of analysis, it is clear that the study area has undergone great population growth from 1990 – 2020.

The second objective was about the extent at which Gishwati forest has been degraded through land use land cover change detection**,** the forestland in 1990 was ever green without any disturbance by human population but in 2000 the forestland has declined at the expense of growing cropland which went in parallel with the growing population. During the period 1990–2000, about 558.5 ha (35.57%) of forest cover were lost. Whilst during this period, 496.5 ha of cropland and 60 ha of grassland areas emerged. This signifies that there is a big part of forest cover which was converted into cropland. From 2000-2010, the forestland and grassland areas increased by 260.76 ha (25.7%) and 10.85 ha (18.3%), respectively while the cropland decreased by 269.52 ha (54.3%). From 2010-2020, forestland and grassland increased by 7.84 ha (0.62%) and 144.63 ha (204.1%), respectively.

The third objective was to discuss the impacts of population growth on forest degradation, the results shown that LULC change and population growth have a strong relationship. As population increases, the need for cultivated land, grazing land, fuel wood, settlement areas

also increase to meet the growing demand for food and energy, and livestock. Population growth and density are indirect factors for LULC conversion through the growing needs for additional lands for farming and grazing as well as demands for tree products (fuel and construction wood).

CONCLUSION

The massive LULC change threatens the loss of quantity and quality of natural forest cover. Several studies and governmental policies indicate that population growth is the principal cause of the aforementioned change. Recent distressing trends in population growth and deforestation of different forest around the world inspired this research. By applying the recent advancement in earth observation (GIS and Remote sensing), the extent to which the forest has been lost in the Gishwati has been assessed in parallel with the growing population, taking the Gishwati forest as a case. The results unveiled that the Rwandan government have been outstanding regarding the restoration project of its forests since huge deforestation has been only observed from 1990 – 2000 while this alarming deforestation trend has been directly remediated by several restoration projects from 2000 – 2020 though there is still a competing trend between the forest cover and croplands. Conclusively, there is still the need for a well-defined mutually beneficial partnership between the government, local communities, logging companies and international norms in forest sustainability. Hence, policies need to be re-enforced through a balanced approach that takes account of the interest of all parties concerned.

RECOMMENDATIONS

Based on the research findings, the following are recommended to:

The government

The reinforcement of laws regarding the control of population growth through family planning and establishes new policies concerning grouped settlements and so as to reduce forest vulnerability as well as the reinforcement of measures of forest protection. Moreover, the study has shown that populations should be supported by alternative source of energy (Renewable source of energy) for them not to relay on forest as source of energy. In addition, the policy of afforestation was found as one of the responses to the degraded forest. We also

suggest increased efforts in the restoration and regeneration of the degraded landscapes in order to achieve future conservation targets.

The local community around the Gishwati forest

The study recommends the full and active participation of local community into the practices of forest management. Moreover, the study proposes the application of Agroforestry and its effective techniques. In addition, local community should respect policies put in place to restore and rehabilitation of forests, develop a sense of ownership for the conservation of forests, accept not to illegally use the forest for any activity other than those recommended by the Government, report any illegal activity carried out in Gishwati forest.

Future researchers

Other researchers must questionnaires so that they can understand the opinions of community around the Gishwati forest. They have to choose the most suitable research methods because not all research methods can be used for all purposes. Further research is needed on how to create jobs that do not lead to the destruction of forests. More research is needed on how to reduce the rate of population growth while science is making it easier for people to survive and reproduce than ever before Moreover, the usage of remote sensing in land cover change analysis needs to be encouraged for the remaining parks/forest order to tackle forest degradation.

REFERENCES

ADB (2000a). Asian environmental outlook 2001, second discussion draft. Asia.

ADB, E. a. (2000). Gender, increase in population and environmental indicators on African countries Abidjah.

Affairs, D. o. E. a. s. (2011). Global population to pass 10 bilion by 2100, United Nations.

Ahrends (2010). predictable waves of sequential forest degradation and biodiversity loss.

Amare (2013). population and Environment. ethiopia.

Baird (2001). Remarks to the planning meeting of the international forest law enforcement and governance conference.

Bank, w. (1988). the economics of land degradation. washington.

Bijendra (2009). impacts of demographic changes on forest and forestry.

Boahene (1998). the challenges of deforestation in tropical Africa.

bongaarts (2009). Human population growth and the demographic transition. new york.

Brown, L. R. and E. C. Wolf (1984). "Soil Erosion: Quiet Crisis in the World Economy. Worldwatch Paper 60."

CSA (2001). population growth and environment. ethiopia.

Dealon (1993). Assessing the relationship between government policy and deforestation

diversity, c. o. b. (2010). Invasive Alien species " Living in harmony with nature.

Drummond, M. A. and T. R. Loveland (2010). "Land-use pressure and a transition to forest-cover loss in the eastern United States." BioScience 60(4): 286-298.

Egenhofer, C. and N. Fujiwara (2003). "The emerging climate change regime: The UNFCCC, the Kyoto Protocol Forever, Kyoto modified… or yet something else." Final Report of a Study Prepared for Environmental Studies Group Economic and Social Research Institute, Cabinet Office, Government of Japan.

Elizabeth, K. (2009). Rwanda states of environment.

FAO (2001a). Global Forest Resources Assessment 2000.

Genet, A. (2020). "Population growth and land use land cover change scenario in Ethiopia." International Journal of Environmental Protection and Policy 8(4): 77-85.

Gerdes, P. (2008). Lunda geometry: Mirror curves, designs, knots, polyominoes, patterns, symmetries, Lulu. com.

Gurgel, A. C., et al. (2021). "Agriculture and forest land use change in the continental United States: Are there tipping points?" Iscience 24(7): 102772.

Karamage, F., et al. (2017). "Modeling rainfall-runoff response to land use and land cover change in Rwanda (1990–2016)." Water 9(2): 147.

kiguru (2013). the impacts of population change on economic growth. kenya.

kinder (1998). the population explosion; causes and consequences USA.

Lambin, E. F. and P. Meyfroidt (2011). "Global land use change, economic globalization, and the looming land scarcity." Proceedings of the National Academy of Sciences 108(9): 3465-3472.

Larry (2006). socio-economic profile.

Lund (2006). Definitions of forests,deforestations,afforestation and reforestation.

Lusweti (2011). Biodiversity conservation. kenya.

Maathai, W. (2005). forest resource management.

madula (2001). Population Dynamics Sustainable Conservation of protected areas sweden.

Malthus (1991). An essay on the principle of population as its affects the future. london, Mr godwin.

Maluleke (2011). Assessing family planning use and its impact in controlling population growth in africa.

Mapulanga, A. M. and H. Naito (2018). Does A Higher Population Growth Cause Deforestation?: A Study of Malawi's Rapid Deforestation, Faculty of Humanities and Social Sciences, University of Tsukuba.

Matiku, P., Caleb M, Callistus O (2013). the impacts of participatory forest management on forest integrity and biodiversity Kenya.

MINITERE, C.-N. (2007). "Final report on the mapping of Rwandese forests." The Ministry of Lands, Environment, Forests, Water and Natural Resources (MINITERE) and The Geographic Information Systems & Remote Sensing Research and Training Center of the National University of Rwanda (CGIS–NUR).

Munanura, I. E., et al. (2014). "Household poverty dimensions influencing forest dependence at Volcanoes National Park, Rwanda: An application of the sustainable livelihoods framework." Natural Resources 5(16): 1031.

nations, u. (2007). world population prospects. new york.

Nsengiyumva, J. B., et al. (2018). "Landslide susceptibility assessment using spatial multi-criteria evaluation model in Rwanda." International journal of environmental research and public health 15(2): 243.

NYANDWI, E., et al. (2011). "ict4d."
Ongugo, e., al (1998). The effect of internal human conflicts on forest conservation and sustainable development.

Ouedraogo, I. (2010). Land use dynamics and demographic change in southern Burkina Faso.

peter (2012). U.N. population control policy Belief.

Piller, A. N. (2016). "Precipitation intensity required for landslide initiation in Rwanda."

Pimental, D., et al. (2015). Impact of a Growing Population on Natural Resources: The Challenge for Environmental Management. The Forum on Education Abroad, Carlisle, USA.

REMA (2009). Rwanda State of Environment and Outlook 2009: . KIGALI.

repetto (1986). soil loss and population pressure.

Rosendal, G. K. (2000). The convention on biological diversity and developing countries, Springer Science & Business Media.

Rutebuka, E., et al. (2018). "Resource dynamism of the Rwandan economy: An emergy approach." Sustainability 10(6): 1791.

Scherr, S. J. and P. B. Hazell (1994). "Sustainable agricultural development strategies in fragile lands."

Seylar, M. (2002). socio- economic impacts of illegal trees cutting Dar es salaam
Shukla, A. K., et al. (2018). "Population growth, land use and land cover transformations, and water quality nexus in the Upper Ganga River basin." Hydrology and Earth System Sciences 22(9): 4745-4770.
southgate (1988). the economics of land degradation. washington.
struhsaker (1997). Ecology of an African Rain forest. florida.
UNFCCC (2002). Report of the conference of the parties on its seventh session. morroco.

Waswa, B. S. (2012). Assessment of land degradation patterns in western Kenya: Implications for restoration and rehabilitation, Universitäts-und Landesbibliothek Bonn.

Westberg, L. M. (2023). Plant Composition and Turnover in Great Plains Conservation Reserve Program Grasslands, The University of North Dakota.

Weyman, e. a. (2011). Does population increase equate to conservation success? forest fragmentation and conservation.

wilson, k. a. (1987). The development of alley cropping as a promosing agroforestry technology. nairobi.

x-Giam (2017). Deforestation can lead to a direct loss of wildlife habitat.