THE EFFECT OF FOREST DEGRADATION ON ECOSYSTEM SERVICES IN RIVER SIRONKO CATCHMENT

BY

NGARUKIYE MUKWIZA STEVEN

21/U/GMSM/14481/PE

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DECLARATION

I affirm that the content contained in this thesis is my own written work and is not copied and previously presented to any university institution that yielded an academic accomplishment and that all the knowledge sites considered have been recognized by means of citations.

Signature……. Date……

NGARUKIYE MUKWIZA STEVEN

21/U/GMSM/14481 /PE.

APPROVAL

This study has been compiled under my guidance and is currently ready for submission.

Signature:……Date……...

DR. MBATUDDE MARIA

MAIN SUPERVISOR

Signature:……Date……...

ASSOC. PROF. BARASA BERNARD

SECOND SUPERVISOR

DEDICATION

I dedicate this portion of work to my family, friends and every scientist in Uganda and around the world

ACKNOWLEDGEMENT

I am thankful to those who added something new and distinctive to the preparation of this study. I am grateful to my supervisors, Prof. Barasa Bernard and Dr. Mbatudde Maria. I am also greatly appreciative of my family for both providing me spiritual and moral support and financial assistance, which have been vital in carrying me this far.

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LIST OF ACRONYMS

CO_2:	Carbon Dioxide
EBA:	Ecological based adaptation
ES**:**	Ecosystem services
ETM:	Enhanced Thematic Mapper
FAO:	Food Agriculture Organization
FGD:	Focus Group Discussion
GHG:	Green House Gas
GIS:	Geographic Information System
GOU:	Government of Uganda
GPS:	Global Positioning System
HEC-RAS:	Hydrological Engineering Centre – River Analysis System
IPCC:	Intergovernmental Panel on Climate
LULC:	Land Use land cover
MCE:	Multicriteria Evaluation
MWE:	Ministry of Water and Environment
NWSC:	National Water and Sewerage Corporation
RS:	Remote Sensing
SPI:	Standard Precipitation Index
UBOS:	Uganda Bureau of Statistics
UNDP:	United Nations Development Programme
UNEP:	United Nations Environment Programme
UWA:	Uganda Wildlife Authority

ABSTRACT

In addition to being essential to the survival of the planet and reducing planetary warming, forests are also one of the simplest and most efficient ways to keep ecosystems zero-carbon. Forest ecosystems in Uganda are at present undergoing high levels of degradation determined by the country's fast population growth, which has occasioned, in augmented need for agriculture, settlements, and industrial expansion. This study therefore assesses the forest degradation and the changes in ecosystem services supply in river Sironko catchment in Bulambuli and Sironko district. A mixed-method approach was used. To examine the spatial extent of forest ecosystem degradation in Sironko and Bulambuli districts, analysis of Landsat images (Landsat 7TM &8ETM) of the study area for 2000 and 2023 was conducted using unsupervised and supervised classification in ArcMap 10.8. Land Change Modeler (Markov chain Model) was utilized for assessing modifications, and land use land cover projections up to 2040. Socioeconomic data was used to study significant drivers of forest ecosystem degradation and ecosystem service changes. The Standardized Precipitation Index (SPI) was important to assess the degree of drought in the study area and Flooding in the River Sironko ecosystem was delineated using the HEC-GeoRAS tool. The study clearly shows that: i) land use types (built-up areas, farmland, and tree plantations) are high on the increase compared to other land cover types in both Sironko and Bulambuli districts. ii) Rapid population growth (31%), agriculture intensification (29%), low employment opportunities (35%), expansion of land for settlement (11%) were noted to be the major drivers of forest and ecosystems degradation. iii). The most supplies affected by forest degradation included soil fertility (20.1%), and Source of food (18%); Ability to reduce floods and droughts; Spiritual sites and Sense of belonging. As results of forest degradation, people, agriculture sector and wildlife are very vulnerable to natural disasters like draught and floods. Appropriate adaptation and mitigation strategies can reduce effects of forest encroachment. This can be done through environmental education, enforcement of environmental policies and population policies; providing alternative sources of livelihood to communities to reduce forest tress.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

Ecosystem services (ES) are ecosystem traits, functions, or strategies that either straight or indirectly improve social comfort (Cuni-Sanchez et al., 2019). Forest ecosystems improve the beauty of the natural environment, provide habitats for organisms, normalize the regional and universal climate, eliminate toxins from the soil, water, and atmosphere, increase soil holding and water quality, allow for fertilization from outside, and seal valuable genetic material that has not yet been revealed (Cudlín et al., 2013; Nunes et al., 2020). Numerous supplementary, legislative, and artistic services are delivered by jungles (Guo et al. 2019). In addition to being essential to the survival of the planet and reducing planetary warming, forests are also one of the simplest and most efficient ways to keep ecosystems zero-carbon (Nunes et al., 2020).

Tropical jungles are home to between 50 and 60 percent of all living things on Earth (Kombate et al., 2022). Mt Elgon, the most notable dormant volcano in this part of the world, it is said to be one of the largest densely inhabited remote regions in eastern Africa. It boasts exceptionally lush and fruitful lands with ideal atmospheric conditions for cultivating crops (Opedes et al., 2022). The roles that trees play in global social, financial, and environmental gains are becoming increasingly apparent (FAO, 2018). For thousands of rural people in developing countries, forests provide employment opportunities, fuel supplies, medicines, and nutritious food that supports a wide range of nutritional needs (HLPE, 2017; Ahammad et al., 2019).

Numerous variables, such as financial growth, individuals' action, and changes in the climate, keep exerting pressure on the planet's natural resources (Barasa et al., 2022). Human populations and the depletion of resources from the environment have grown greatly in many regions of the world, while ecosystems' capacity to heal—particularly food systems—has decreased. As a result, both natural and human systems are becoming more delicate (Nandy et al. 2015; Guo et al. 2019). As the land surface has shrunk to about fifteen percent, Uganda has currently lost sixteen percent of its forests and woods. This has had an impact on the products and ecological services that the ecosystem provides (FAO, 2018).

The expansion of towns, grazing land, and cropland was spurred by the growing global need for food, energy, shelter, and connectivity (Gourevitch et al., 2016). The expense and devastation of the natural environment are due to these deviations in land use altering the hydrologic, living thing, and greenhouse gas cycles globally (MEA, 2005; Gibbs et al., 2010). The products that forests provide primarily impacted by changes in how land is used, which can result in a reduction in the covering zone as well as alterations to the environment's structure (FAO, 2018). The spatial distribution of varied land cover areas improves the connections between the land and atmosphere (Motta et al., 2021).

River Sironko basin, much as it is in other areas of the Elgon region, is not spared from the ecosystem degradation. Landowners and residents in the River Sironko basins that extend up to the riverbanks make use of their land as they see fit, which results in the completely organic collection of land use activities in conjunction with the river, most of which appear to degrade and impair the

ecosystem. These activities include farms, the extraction of sand, development, manufacturing, and forestry (Kasangaki et al., 2008; Turyahabwe et al., 2020).

Because of high-rate jungle degradation, global warming is a fact of life and one of the most burning issues of our day (Galan-Acedo et al., 2019). It has worsened the ability of ecosystems to provide the different services hence worsed disaster like drought, flood and landslides (Clinton-Ezekwe et al., 2022). Many academics and experts now regard climate change as a given and describe it as the greatest threat humanity has ever faced (Nunes et al., 2020) and there won't be a quick fix (Keohane et al., 2011). The primary sources of the rise in CO2 levels in the air are the combustion of fossil fuels, various land uses related to deforestation and burning, and the raising of livestock (European Union, 2020). As a result, carbon storage becomes more challenging (Clinton-Ezekwe et al., 2022).

On an international scale, people are now bearing the impact of forest degradation, which brought about warming temperatures (Raimi et al., 2021). The lowest advanced nations, including those in Africa, are the worst equipped to handle these effects. Uganda is without a doubt among the nations that have been found to be highly susceptible to warming temperatures (CIGI, 2007; Mumba et al., 2016). The impacts have become widespread and have involved a shortage of food, drought, and flooding. This presents a significant, multifaceted development issue as well as a means of subsistence (Mumba et al., 2016).

In Uganda, the consequences of warming temperatures have resulted in the loss of human and animal life as well as the devastation of crops by drought (Ugonabo et al., 2023). Droughts have psychological, ecological, and financial impacts on a range of factors, such as: depletion and loss of nutrients from exposed soils due

to wind and water erosion; damage or breakdown of forests; lack of water and reduction of plant life; move or extinction of wildlife; excessive harvesting and diminished water reservoir replenishment; outcomes on the safety of water; reduced agricultural production; conflicts between water consumers; reduce in public health; etc. (Camilloniet al., 2020; IRC, 2023).

In northern Uganda, the invasion of desert locusts has resulted in crop loss and the destruction of bathrooms because of flooding of rivers and lakes, including the Nyamwamba, Lake Kyoga, and Lake Victoria (Nuwagira et al., 2022). Recent severe weather irregularities observed in Eastern Uganda, involved flooding and ice melting atop Mount Rwenzori in the Kasese district, islands shifting in Lake Victoria (World Bank, 2019; Nuwagira et al., 2022). Floods are the primary cause of over 90% of the destruction of property and damaged means of subsistence in Asia (Smith, 2013; Paul et al., 2019). Secondary disasters like landslides, various diseases transmitted by water, and soil erosion are caused by this unforeseen event (Cao et al., 2016).

Monitoring and controlling the shifting patterns of climate change brought about by land use, as well as how they have impacted the area covered by forests, the ecosystem services, nearby communities, and the likely future trends, are essential for guiding land use forecasting and environmental resource management advancements. The available literature on impacts of forest ecosystem degradation and floods and drought on ecosystem supplies in River Sironko is insufficient for guiding these processes since it does not account for recent developments and does not focus on specific districts as this study does. Furthermore, there is not much research in the field on vulnerability analysis, land

use estimates, and impact of drought and floods. This study was created to assess the effect of forest degradation on ecosystem services considering shifting land uses and future scenario forecasts.

1.2 Problem Statement

Forest ecosystems in Uganda are at present undergoing high levels of degradation determined by the country's fast population growth, which has occasioned, in augmented need for agriculture, settlements, and industrial expansion. Because of that, Uganda is now experiencing shorter or longer rainy seasons, which bring floods and worse droughts, particularly in the country's east and northeast where Bulambuli and Sironko fall. The capability of ecosystems to grant important ecological and socioeconomic goods and provisions is diminished by forest degradation endangering the livelihoods of reliant local peoples. Effects of forest degradation have already resulted in poverty, erratic rainfall patterns, copious volumes of precipitation, and extremely high temperatures, immigration, loss of culture and disputes over natural assets like land.

There are limited available research on effects of forest degradation on ecosystem services and supplies in Uganda and East Africa. By examining the extent and establishing the drivers of forest ecosystem degradation, determining the changes on ecosystem services supplies, and mapping the number of forests ecosystem between 2000 and 2023 and vulnerability analysis to impacts of drought and floods, this study closes the gap.

1.3 Objectives of the Study

1.3.1 General and Specific Objectives

The main objective of this study was to assess the effect of forest degradation on ecosystem services supply in River Sironko Catchment

Objectives

1. To examine the spatial extent of forest ecosystem degradation in Sironko and Bulambuli districts between 2000 and 2023
2. To establish the drivers of forest degradation and forest ecosystem services in Sironko and Bulambuli districts
3. To determine the changes in forest ecosystem services in Sironko and Bulambuli districts

1.4 Research Questions

1. What is the spatial extent of forest ecosystem degradation in Sironko and Bulambuli districts between 2000 and 2023?
2. What are drivers of forest degradation and forest ecosystem services in Sironko and Bulambuli district?
3. What are changes in ecosystem services in Sironko and Bulambuli district?

1.5 Significance of the Study

The study findings provided key information on the effects of forest ecosystem degradation and floods and drought on ecosystem supplies. With the help of different scientific models applied, viable recommendations were raised. Both Scientific models and GIS and remote sensing techniques were used to study the state of forest vegetation cover in the study area where areas with the most forest

cover loss and damages were highlighted. Predicted Land use and cover in the Bulambuli and Sironko was availed thanks to models. In addition, climate change risk vulnerability was assessed for different sectors for better mitigation and preparedness in case of climate change disasters.

To help the National Forestry Authority and natural resources development organizations review their policies on forest conservation and land management. The study's findings provided important information about the condition of the forest vegetation cover on the slopes of Mount Elgon by highlighting areas with the greatest losses and damage to the forest cover. The study can be used on a basis by organizations like the Ministry of Water and Environment and the National Environment Management Authority at all levels to evaluate future landscape patterns and their potential adverse effects on forest ecosystems and other elements of the environment.

The study efforts could benefit future researchers through the new information it provided about climate change, LULC changes, and disaster impacts and preparedness, thanks to the study's findings.

1.6 Scope of the Study

The research tasks were carried out in the Sironko and Bulambuli District, which is situated in Eastern Uganda's river Sironko environment on the slopes of Mount Elgon in 2023. The study concentrated on how the changing forests affected the ecosystem services provided by forests in the regions on the Mt. Elgon slopes. Forest area coverage, delivery, and anticipated future shifts and changes in land use types were evaluated. The presumption was that adjustments in land utilization resulted in variations in the arrangement and extent occupied by

forests. This study used data for the Sironko and Bulambuli districts over 23 years (2000-2023) to determine changes in land use and forest cover. An estimate for alterations in trees and land use/cover for the years 2023 to 2040 was then constructed depending on the information provided.

Baseline data was collected in all sub-counties located in our study area. Variables assessed included: soil fertility, source of food, ability to reduce floods and drought, sense of belonging, spiritual sites, medical plants and source of pasture. Data collection was done for a maximum period of two months. One month through the pouring period (April) and another one month in the dry period (February).

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

The research variables' larger context is presented in this chapter in relation to earlier academic publications. In terms of the study's aims on the effects of forest ecosystem services degradation and floods, establishing drivers of forest degradation and drought effects on forest ecosystem services and supplies. It covers a theoretical and thematic review of pertinent literature.

2.1 Forest ecosystem

The United Nations Food and Agricultural Organization of the International Community published its international woodland Ecosystems Appraisal (FRA) study in the year 2010 (FAO, 2010a). Predict the overall land area of the worldwide level represents thirty-one percent of jungles along with other trees surrounding lands. While the ratio is about forty percent split between open and closed vegetation, at tropical and subtropical latitudes, dry forest occupies 42%, twenty-five percent by swampy and tropical forests, and thirty-three percent by moisture woodland (Bodart et al., 2013). Africa is home to the biosphere's major part they represent anywhere from seventy to eighty percent of woodlands in arid woodland settings (Murphy & Lugo, 1986).

Forest ecosystems hold the greatest earthly species in the world (Primack, 2014). Very genuine, tropical forests have the uppermost biological abundance among various taxonomic classification (Hillebrand, 2004), and these have been enduring the greatest amount of forest clearing in today's world (Hansen et al. 2013). Several species seem completely restricted to timberland ecosystems (IUCN, 2019; Galan-Acedo et al., 2019c).

1145 km2 of Mountain Elgon trans boundary Park's rainforest serves as a significant as a lot of citizens in the nations of Kenya, Uganda, and various other Nile Basin nations' freshwater intake region nations. (Ongugo et al., 2014). Many rivers, including the important River Nile tributaries River Sironko and River Manafa, originate on the mountain. 4 habitats or areas of foliage can be observed at the mountain of Elgon foothills because of altitudinal fluctuations. The mid-slopes (2000-2500 m over the surface of the earth), which were formerly wide-open forests and have since been extensively used for agriculture, and the lower slopes (below 2000 m higher than water line), that were previously wide-open forests, the bamboo zone (2,500–3,000 m above ocean floor), and the (Above the bamboo-covered area) Afro-alpine region constitute these ecosystems. The Afro-alpine sector is primarily made up of moorlands, marshes, and solid materials including big stones The Afro-montane moist forest on the mid-slopes (2000-2500 m over the surface of the earth), which was once controlled by Juniperus procera, Hagenia abyssinica, Olea welwitschia, O. hochstetteri, Prunus africana, Podocarpus falcatus, & Podocarpus latifolius varieties of plant, has become an official reserve. Before the forest was designated as a national park, many of these species had been over farmed (UFRIC, 2008). During one component of the FACE initiative in the mid-1990s, the woodland was replenished with native species.

2.2 Forest ecosystem services and degradation

The natural world is very necessary to humanity's ability to survive and thrive (Fisher et al., 2009). The Millennium Ecosystem Assessment (MA, 2005) established the notion that individual well-being depends on environments and how these connections might be noticed and described by a concept of ecosystem

services. This was a significant turning point in the research of ecological advantages. The M.A. found that more than 6% of the benefits provided by environment are being harmed or changed, endangering human welfare in the future (La Notte et al., 2017).

The tale of civilization is basically the story of people striving to get goods while looking for protection from the weather. The story took a tiny turn around ten thousand years ago when humans began to truly manipulate the physical environment. We felt quite honest. Humankind have always acknowledged the importance of what we now regard to as environment amenities—managing the renewable resources offered by cultivating and rearing livestock with the goal to boost output (Fisher et al., 2009).

2.2.1 Ecosystem service classification

The first step in implementing an environmental service strategy of conduct is to choose which items to classify or analyse (and assess) from an order of facilities. The ideas and tenets of the conceptual framework, upon which categorization schemes are constructed, usually mirror the makeup and significance of the objects supplied. They therefore contend that to highlight the underlying concepts, it is imperative to investigate the primary categorization schemes. For example, the Millenium Ecosystem Assessment (2005) attempted to classify four kinds of advantages associated to ecosystems:

1. ***Providing products and services*** (food, clothing, energy, and biological materials, for example).

2. ***Regulating activities*** (including preventing disease, reducing climate change,

easing the incidence of extreme events, and administering and purifying water)

3. ***Supplementary services*** (like initial nutrition production and turnover); and

4. ***Artistic services*** (such eco-friendly travel, recreational opportunities, aesthetically beautiful surroundings, and religious characteristics).

While it's not truly a classification structure, this classification provided a strong basis for the creation of potential for ecological services and supplies study. In the cascade model, auxiliary amenities are perceived as "as opposed to a "good," or a "utility" (Haines &Potschin, 2012). Following the MA, the TEEB classification (2010) explicitly mentioned the cascade architecture but distinguished between services and benefits more precisely. The idea of TEEB's auxiliary operations was not further considered. Fisher and others (2009). Alternatively, a new type of "natural supports" was introduced, comprising "maintain ecological diversity" and "maintain organic activities."

2.2.2 Ecosystem degradation

The main risks to Uganda's biodiversity persist, including habitat loss, alteration, and pollution in addition to unsustainable harvesting, pollution, and the introduction of foreign species (Zulu, 2008). According to reports, Uganda's regional endemism centers are in the peak's jungles of Mount Elgon (Plumptre et al., 2003). In 1951 then 1992, significant areas of Mount Elgon were formally designated as national conservation areas and wilderness areas. Local populations rely on this ecosystem in order to provide products and amenities including lumber, charcoal & stakes, for construction despite the high protected status of this environment.(Ongugo et al., 2014). The highest reported loss of biodiversity caused by humans to an ecosystem is thought to have been caused by the decline

of tree species in Eastern Uganda (Witte et al., 2010). According to a 2004 estimate, Uganda is losing biodiversity at a high rate of 10- 11% a decade. Even though these numbers are substantial, they are lower than the 1 percent annual complete destruction of the world's forests has been noticed (Motta et al., 2021). The bamboo zone is a principal supply for nutrition, poles, and fuel wood intended for the nearby settlements of Mount Elgon. Communities are permitted by national park regulations to gather For food, harvest fresh stems of bamboo and dry bamboo to be utilized as poles and flames (Ongugo et al., 2014).

In Uganda, there has been a significant loss of tree species, and unfavorable trends are still present (Motta et al., 2021).

In addition to converting woodland and undeveloped fields for these uses, it is common procedure in Uganda to grow crops, burn, and cut down forests for grazing and wood energy (Zziwa et al., 2011). The major kind of vegetation is savanna, which differs according to the species mix and tree abundance. In this Eco region, observations of roughly 80 species have been made (Motta et al., 2021). While plants from the south such as Bombaxcostatum, Combretumelliotti, Cordylapinnata, Entadaafricana, Parkiabiglobosa, Prosopisafricana, and Pterocarpuserinaceus are also found in the south, Acacia seyal and Lophiralanceolate are known to occur in the north. Therefore, along with the shift of woodland to agricultural and grazing land, the deterioration of woodland resources brought on by wood collection, pit extraction, and biomass combustion are primary causes of disappearing forests (NEMA, 2010).

Over seventy percent of jungles are on family-owned land, where degradation is a typical occurrence. Which, according to Kayanja and Byakagaba (2015), is

neither preserved nor regulated. The decline of biodiversity and the strain on the environment's advantages are among the most pressing global challenges. The main causes of the decline in biodiversity are changes to the landscape brought about by destruction (Fandohan et al., 2011).

These changes usually happen in phases; however, they can have a significant impact on habitats since they are linked to reductions in the diversity of animals and the number of individuals. Many components of ecological biodiversity are difficult to track globally (Motta et al., 2021). However, it gets easier to evaluate changes in the extent and temporal arrangement of natural ecosystems. Land cover alteration is now the most useful method for tracking stressors on ecosystems as well as biodiversity globally (NEMA, 2009).

Fully intact forests have the largest percentage of carbon from organisms in the earth when weighed against agricultural land (Barasa et al., 2013; Mugagga et al., 2017). The forms of land habit and cover have a significant impact on the quantity of carbon absorbed in the loam (2013), according to Barasa et al. (2017). Because of this, there is a beneficial correlation between soil carbon and the territory covered by rainforests. This means that changes in land utilization that influence the size of woods influence soil carbon, which in turn influences the internal structure of the forestry surroundings, influencing the quantity and variety of woodlands. The most frequently mentioned adjacent roots of changes in land use and land cover in Africa are wood extraction, agricultural development, and infrastructure expansion (Motta et al., 2021). Deforestation's negative environmental repercussions frequently inspire nations that rely heavily on wood for fuel to devise solutions to the issue (FAO, 2021).

Galal (2009) examined the changes in how land was used and covered along the Nile River's banks in Sudan and discovered that although the amount of tree cover had shrunk, the region that was utilized for residential, commercial, and agricultural reasons had increased. The reduction in the amount of forest land implies a shift in the routine functions of natural ecological functions as well as the framework of the ecology. The shifts in the canopy of forests were caused by alterations in land use laws that were imposed by the administration and the local population to use the area for residences, heaters, and infrastructure development. The analysis concluded that these activities reduced the territory's ecological worth and output. The literature (e.g., Mugagga et al., 2012; ACCESS, 2015) suggests that the present research region has seen modifications that should cause the natural environment of forests to become fragmented.

2.3 River Sironko catchment and forest ecosystem service changes

Together with the Victoria Nile, the Mount Elgon area provides much of the water for the Lake Kyoga watershed, which constitutes one of the most important in Uganda and a significant portion of the Nile basin due to its numerous rainfed rivers (NEMA, 2008; K. Geussens, et al., 2019). Locally, residents of the Mount Elgon region and the adjacent areas use the water for farming and residential usage (UWA, 2009). The freshwater that Mounts Elgon provides is used by numerous sizable businesses. First, water from multiple streams and rivers, including the Manafwa and Sironko, is treated and distributed to clients in urbanized areas by the state-owned National Water and Sewerage Corporation (NWSC). Additionally, rice is farmed in the swamps of the river Manafwa under two sizable watering systems: the commercial project and the government-run

Doho rice scheme. These businesses rely on Mount Elgon's water supply, and the purity of the water affects their bottom line (K. Geussens, et al., 2019).

The daily lives of those residing in the districts of Trans Nzoia, Mount Elgon, Kapchorwa, Sironko, Bulambuli, and Mbale, Kenya, and Uganda, are predominantly reliant on small-scale farming and natural resource-based goods derived from the Mount Elgon habitat. Numerous are susceptible and impoverished small-scale agriculturalists who mostly practice farming for survival-defined agricultural structures. Agriculturalists face constraints from a variety of sources, including small land assets, insufficient collaborative organizational structures, insufficient facilities, few processing advantages, market information access, and the distance of urban purchasing shops (Easter African community, 2007; Mugagga et al., 2012).

The river Sironko environment faces conservation difficulties. Since its establishment, farmers from nearby villages who depend heavily on forest resources for their source of income have put at risk the National Park (Sassen et al., 2013; Vedeld et al., 2016; Petursson and Vedeld, 2017). On-farm conservation is an additional issue. A rising number of agriculturalists are farming inappropriate land, like riparian areas that are prone to flooding and extremely steep hills. According to Mugga et al. (2012), this leads to in extreme runoff, erosion, and possibly landslides. Significant amounts of silt are carried into Mount Elgon and the river Sironko systems, significantly lowering the water purity. Many techniques, such as terracing, contour trenches, grass strips, mulching, agroforestry, and strengthening shorelines with buffer strips, can be used by landowners to decrease erosion (UNDP, 2013). Although many growers

have embraced at least one soil conservation strategy, implementation and adherence rates are still too low overall. According to earlier research (MWE, 2012; Barungi et al., 2013), low adoption may be the result of scarce labor, machinery for farming, and extension services.

According to Wichern et al. (2019), floods and drought caused by forest degradation have a direct consequence on the majority of harvests in the Elgon region, which reduces the compatibility of all important crops with the exception of sorghum. The primary factor restricting the viability of bananas, beans, maize, groundnuts, and coffee in the center southwest and northeast of Uganda, he continued, was rainfall that produces floods. In Uganda, producing rain-fed crops is a crucial source for income and food safety for farmers and their families. Due to their reliance on agricultural production, households experiencing food insecurity and poverty are more susceptible to the effects of forest ecosystem degradation and rising temperatures (Wichern et al., 2017).

According to several studies (Netherlands Space Office, 2018; Nakalembe, 2018), the northeast and easter of Uganda is one of the nation's most susceptible regions of the country, with severe shortages of food and an elevated risk of crop collapse from protracted dry spells and droughts. Extreme weather-related calamities in recent times have also brought temperature disruption and unpredictability into the public eye and conversation.

Considerable forests change has been caused by floods and landslides, particularly in the districts of Bududa and Kasese. Irish and sweet potatoes, as well as other root crops including cassava, have been damaged by floods. Kabale–Kigezi experienced a catastrophic hunger in 2004 as a result of excessive rainfall,

particularly in the subcounties of Muko, Bufundi, and Karambo. A rise in crop pests including bean aphids, crop failure, and the frequency of bush fires have all been caused by droughts since 2007 (NAPA, 2007).

The study of Uganda's precipitation variance has demonstrated how diseases and insect pests have affected tomato output because of extreme occurrences including floods and, most notably, droughts (N'dakpaze et al., 2023). In general, the districts of Kampala, Namutumba, and Mbale had an upsurge in the rate of pest incidence. Pest population growth is correlated with variations in temperature and wind movements. This implies that there may be a significant tendency in the correlation between rising pest populations and forest degradation factors (Skend et al., 2021; N'dakpaze et al., 2023). Tomato output loss and quality are impacted by invasive pests including thrips and extracting leaves (M. Call and Gray, 2020; Gabriel, 2021).

Elum et al., (2017); Nsubuga et al., (2018), and Nuwagira et al., (2022) agreed that temperature levels and high downpours which led to drought and floods have affected soil fertility in different parts of the country including Elgon region. Study by Diksha et al., 2024 noted that Climate risks impacted fruit crops at different phases of growth and development, causing problems like sunburn damage, fruit cracking, inadequate pollination, reduced panicle emergence, poor fruit set, delayed ripening, reduced color formation, and lower sugar content, all of which lower fruit quality and yield.

The Ministry of Water and Environment (MWE) has determined that the five industries most susceptible to the adverse impacts of global warming brought about by forest degradation are farming and animal products, water, energy,

residential areas, and transportation (GOU, 2015). Global warming also poses a danger to the attainment of Uganda's 2040 Vision, which calls for the country's transformation from a rural to a contemporary, wealthy civilization by 2040 (NPA, 2007). Five-year National Development Plans (NDPs) are how the vision will be realized. NPA, 2020 states that farming, services, industry, and water are identified as vital components of the NDP. Africa's limited ability makes it among the areas on Earth most sensitive to warming temperatures and change, according to the Intergovernmental Panel on Climate Change (IPCC, 2007, 2014). Primarily in the fields of disaster preparedness and expansion, finance, sociology, anthropology, geography, health, universal alteration, and the study of the environment, the vulnerability concept has been applied for nearly fifty years (O'Keefe et al., 1976; Timmerman, 1981; Cutter, 2012; Bergstrand et al., 2015).

2.4 Literature gaps

There are limited studies on effects forest degradation on ecosystem services and supplies in Uganda and East Africa. While many studies focused on land use/land cover, very little have made land use and land cover projections both in Uganda and in the region. Disaster vulnerability analysis is another area that is not well documented in both this area and Uganda at large.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Description of the Study Area

The river Sironko ecosystem is found in the Bugisu sub-region, of Eastern Uganda. The targeted ecosystem is forests including Mt Elgon. The biggest part of this ecosystem is in Sironko and Bulambuli districts (3.1). River Sironko ecosystem lies between 33.5° - 36°E and 1° - 5° N. About 3,980 meters above sea level, in Malere village, Bugitimwa sub-county, Sironko district, is where the River Sironko rises. It feeds down into the Lake Opeta-Bisina system after flowing across the Okwapi-Apapai-Kakole-Kung wetland system and several studies have shown that volcanism dominates the territory around Mt Elgon's geological structure (Turyahabwe et al., 2020).



Figure 3.1: River Sironko ecosystem in Eastern Uganda

Mount Elgon territory experiences a humid subtropical climate. The average lowest and maximum temperatures are also 15 and 28 degrees Celsius, respectively. Typically, the average rainfall per year is around 1500 mm (Jiang et al., 2019). The ecosystem has various types of geology but the most dominant include volcanic mudflow (38%), nephelinite lava (22%), and alluvium or lacustrine deposits (20%) (Isabirye et al., 2004). Numerous natural and man-made elements, including height, aspect, soil, climate, and ways of using land, have an impact on the arrangement of flora in this region. These include mixed montane forests found at the altitude of 2,500m, hardwood and highland canopy of trees found within a range of 2,400m and 3,000m, and moorland, which is found above 3,500m (Scott et al., 2011). Nevertheless, civilization has a significant impact on plant life in nature (Wesche, 2002).

3.2 Research Design

Approaches of data gathering and analysis which were very interactive and participative were used to obtain socioeconomic data. This research used a mixed-method approach, meaning that both quantitative and qualitative data collection techniques were used. Data collection followed a stepwise approach, which included:

Households from the administrative units (town councils and sub-counties) that the River Sironko passes through were the focus of the socioeconomic data collection. However, each respondent was chosen at by chance. An early stakeholder interaction with the district representatives, as well as those that impacted by forest degradation effects, sub-counties and town councils, inspired this purposeful selection of sub-counties.

The number of households studied were the result of the method for estimating the model scope by Krejcie and Morgan (1970). Krejcie and Morgan came up with a table for determining the sample size for a given residents for easy source. From this method, 278 families were carefully chosen from a population of 1000 households.

3.3 To examine the spatial extent of forest ecosystem degradation in Sironko and Bulambuli districts between 2000 and 2023

Landsat and sentinel imagery for two years of 2000 and 2023 was freely downloaded and acquired from https://earthexplorer.usgs.gov/ with a tiled spherical location of path 170, row 059, and T36NXG respectively. The assumption was that a 23-year period was enough to observe the LULC changes in the study area. The sentinel imagery of 10m resolution was considered for only 2023 to improve the visual interpretation of the current vegetation changes. Landsat 7 Enhanced Thematic Mapper (ETM) was considered for the year 2000 because of its availability, low cloud percentage cover (0-2%) medium spatial, and high temporal resolutions of 30m.

Besides, Landsat-7 (L-8) and Sentinel-2 (S-2) services, a group of medium-resolution satellite imagery, a group of medium-resolution imagery from satellites, offer excellent temporal resolution data, a quick revisit time, and a rich spectrum configuration, making them suitable sources for time series feature extraction (Liu et al., 2020).

3.4 To establish the drivers of forest degradation and forest ecosystem services in Sironko and Bulambuli districts

3.4.1 Socio-economic data collection

For the household survey, a structured questionnaire was used to gather information from communities having an emphasis on the home's leader. The questionnaire A multi-stage sampling technique was adopted. In order to do away with the conventional data input methods connected with gathering data using paper-based questionnaires and for safe keeping, a purposeful selection of sub-counties, parishes, and villages was uploaded to the KoBo Collect program, and data was gathered via a mobile cell phone. methods for gathering data, such as questioning and interviewing, quality assurance, and research ethics. In addition, a semi-structured questionnaire also programmed in the KoBo Collect software was used to collect data from institution administrators on institutional vulnerability to floods and drought. These included public offices, security installations, healthcare facilities, schools, and public markets among others.

The data collection methods that were adopted to execute qualitative studies are desktop studies, discussion groups, conversations with key informants, and observation. The leadership wing, scientists, and district lawmakers were the subjects of key informant interviews. To gather information on the causes of forest degradation and ecosystem services, a key informant guide was used. Participants from the community as well as district and sub-county officials participated in conversations in focus groups.

3.5 To determine the changes in ecosystem services supplies in Sironko and Bulambuli districts

To determine the changes in ecosystem services, several approaches were used as explained below. Forest degradation caused natural disasters including floods and drought. Other services were hard to quantify hence the mapping of floods and drought.

A persistent aspect of climate change known as drought is when there is an extended period of unusually little rainfall (compared to what is considered normal) (Wilhite et al., 2019). Rainfall data for the River Sironko ecosystem was obtained from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) for the period 1990-2021 (31 years).

Flooding is an overflow of water that submerges usually dry land. The datasets included rainfall, elevation, land use/cover as well and stream geometry data.

To determine ecosystem changes caused by forest degradation that led to flood and drought in Sironko and Bulambuli districts, focus group discussion and interviews were conducted. Respondents identified how drought and floods have impacted them in different areas of their lives. Farmers, district officials, technocrats and students were involved in group discussions and interviews to assess the impact of climate risks on ecosystem services supplies in Bulambuli and Sironko districts. The supplies included provisioning (soil fertility,source food: fruits, medical plant, spices, pastures for livestock), regulating services (Ability to reduce the impact of extreme climate change events e.g., by slowing down water runoff/floods, reducing soil erosion and droughts.) and cultural services (Spiritual sites and Sense of belonging).

3.6 Vulnerability assessment

The methodical analysis of components that are vulnerable to harm from the consequences of environmental risks is known as vulnerability assessment. Unfavourable circumstances, such as physical, social, economic, and environmental variables that make components in danger more susceptible to the effects of hazards, are referred to as vulnerability (UNISDR, 2015).

Vulnerability assessment in the River Sironko ecosystem was conducted based on sectors developed under the third National Development Plan (NDP III). The selected sectors include agriculture, social, tourism. These sectors were selected because of vulnerable they are to the impacts that floods and drought. It was therefore important to assess how vulnerable Sironko and Bulambuli was to provide awareness that might save live in case of disasters. The elements assessed in the respective sectors were presented in Table 3.1 below.

Table 3. 1: Elements/indicators considered for vulnerability assessment by sector

Sector	Elements/Indicators	Data Source
Agriculture	Croplands	Sentinel-2 Image (2022) extraction
Social	Population	Projected population 2022 (UBOS)
	Children (< 6 years)	UBOS Census 2014
	Elderly (> 65 years)	UBOS Census 2014
Tourism	Protected Areas	UWA 2018

3.7 Data analyses

3.7.1 To examine the spatial extent of forest ecosystem degradation in Sironko and Bulambuli districts between 2000 and 2023

Using the district's administrative boundary of 2022 obtained from the Uganda Bureau of Statistics, the Sironko-Bududa district boundary was processed using the overlay tools in ArcMap 10.8 before land use/cover image classification. Sironko- Bulambuli districts boundary were used to mask out the multi-spectral composite imagery for 2000 and 2023 before applying a classification scheme. The hybrid classification scheme (supervised and unsupervised) was adopted to obtain the composites of each year. Several spectrum photographs are combined to create the composite image. A higher visual representation is sought by the creation of composite images. to enhance object perception and sample selection (Kelik Nugroho & Permadi, 2019). The composite imagery was obtained from three variants of spectral band combinations of 4,3,2 (2023) and 3,2,1(2000) to acquire true colors.

The Dark Object Subtraction method was used to visually adjust the resampled photos (Lu & Weng, 2007) to minimize the impact of the atmosphere on the sensor (Chander et al., 2009; Mustak et al., 2016). Dark Object Subtraction was used because it searches and removes dark pixel values. However, to improve the accuracy of output from the year 2000 despite its spatial resolution, control points from Google Earth images and field data (ground truthing data of 2023). 680 GPS points were gathered. Each land use class had 85 points collected coupled with the random points generated (Rodriguez-Galiano et al., 2012; Osunmadewa et al., 2018).

Direct observation entailed evaluating various land use systems, such as habitation trends, agricultural practices, infrastructure expansions, tree plantations, wetland and woodland areas, and areas of the forest that appeared to have been invaded.

3.7.1.1. Accuracy Assessment

Evaluation was performed by computing reference points from the reference images of the years in question randomly selected. Assessment of accuracy was carried out by developing confusion matrices for each land cover map with sample in the testing data set from ground truthing. Classification performance was evaluated based on Kappa index of agreement. Only producer's and user's accuracies for each type of land cover were also estimated, and the map performance was analysed by means the k statistic using Cohen (1960) index (Herold et al., 2005).

3.7.1.2 Land use/cover Projection

The projection to 2040 was induced by the country's vision 2040. The program Land Change Modeler (Markov chain Model), created by Idrisi 17 Andes, was utilized for assessing modifications, its overall contributors to shift, and the possibilities for transition. For trend analysis, grouped territory-use/cover maps from 2000 and 2023 were imported into the analysis program. Hectar units were used to set the advantages and disadvantages in the area for each form of land utilization or land cover.

The Markov chain model is chosen for this investigation because it predicts future shifts by announcing the alteration in LULC from a single instance to the next (Subedi et al., 2013). The CA-Markov approach integrates cellular automata and

the Markov chain to foresee how the traits and trends of LULC modifications over the years, give a greater awareness of the causes that trigger forest shifts and produce future land use and land coverage prospects to enable the creation of legislative interventions.

Land use surveillance, ecological modeling, simulation modifications, LULC trends, and predicting the degree of Land Use and Land Cover and the sustainability of upcoming growth in land in an area of concern frequently use the Markov chain model. (Subedi et al., 2013).

Therefore, the IDRISI software version 18 (CA-Markov model) was utilized to forecast future LULC changes for Sironko-Bulambuli. The subsequent exact procedures were carried out while accomplishing this:

i. LULC visualizations for the years 2000 and 2023 were utilized to create an image of the change in likelihood. For acquiring the likelihood of a transition picture, 2000 and 2023 are going to be considered.
ii. Using the likelihood of transitions from the year 2000, the LULC for the year 2022 was generated employing the CA-Markov model technique.
iii. The multicriteria evaluation (MCE) module's limitations and components was used to calculate the shift readiness image. The change in probability photos, base map, and transition suitability image will all be used to predict the LULC for the year 2040.

Seven major Classes with LULC were found in the Siroko-Bulambu districts aimed at a specific period of 2000-2023. These included Built-up areas, Bushland, Grassland, Forests, Farming, Tree plantations, Wetlands, and woodlands as described and illustrated in the Table below.

Table 3.2: description of different LULC categories in the sironko-bulambuli districts

LULC category	General description
Built-up areas	An area characterized by settlements and roads
Bushlands	These are regions with little primary and secondary wildlife and little flora (shrubs). Dispersed tree species like Lantana camara, Acacia, and Ficus grow in the bushlands.
Forests	Land with a tree canopy that is sealed off to block sunlight from reaching the earth's surface and may at some point discourage ground-cover growth
Grasslands	Short grass dominated the vegetation in these wide spaces, and there were only a few solitary trees.
Farming	The land is covered with both the production of crops on a small piece of land for house use and large scale using advanced and expensive technologies.
Tree plantation	Land covered by specific species of trees *(Eucalyptus, Bamboo, Cornferious)* for commercial purposes.
Wetlands	These refer to places that are shallow and either periodically or constantly flooded; hydrophytic plants typically grow there. Papyrus reeds, Echnochloa, Miscanthidium, Phragmites, and Pistia were all members of this class.
Woodlands	Land covered with densely scattered trees with grassland underneath

3.7.2 To establish the drivers of forest degradation and forest ecosystem services in Sironko and Bulambuli districts

Social economic data was analyzed in SPSS software version v30 and were presented in tables in both frequencies and percentages. Area coverage of forests in both Sironko and Bulambuli districts were clipped from a clarified 2023

Satellite image to establish the extent of forest degradation. This was coupled with Ground truthing data using GPS which was presented in tables**.**

3.7.3 To determine ecosystem services changes.

Social economic data were analyzed in excel v19 then SPSS software version v30 and were presented in tables in both frequencies and percentages.

3.7.3.1 Floods and drought modelling

The Standardized Precipitation Index (SPI) was important to assess the degree of drought in the study area. The SPI was computed using the Drought Indices Calculator (DrinC). It involved several steps including data collection and preparation, SPI calculation, spatial analysis in GIS and mapping and visualization. The droughts were categorized based on SPI values as described by (McKee et al., 1993; Guttman, 1999 Maca et al., 2016).

Flooding in the River Sironko ecosystem was delineated using the HEC-GeoRAS tool. This flow includes data preparation in GIS, hydraulic modeling in HEC-RAS, and post-processing the results back in GIS .The flood extents were categorized into flood hazard intensities based on water depth i.e., very high (>2m), high (1.5m-2m), moderate (1m-1.5m), and low (0.5m-1m).GPS coordinates were picked at the degraded site coupled with photography and direct observation to support the accuracy of the study.

3.7.3.2 Vulnerability analysis

In assessment, due to data limitations about the elements at risk, the vulnerability was computed based on the location of the elements and the intensity of the hazard. Components with "extremely minimal" and "low" intensities of any

hazard were classed as having low susceptible status, while components with "moderate," "high," and "very high" concentrations were categorized as having high susceptibility. The National Risk and Vulnerability Atlas of Uganda (2019) were the source of this vulnerability assessment methodology. Before vulnerability assessment, the sensitivity of elements to hazards were undertaken. Table 3.3 presents the sensitivity of elements to different hazards.

Table 3. 3: Sensitivity of elements to the different hazards

Hazard	Elements sensitive to the hazard
Drought	Croplands, population, protected areas
Floods	Croplands, population, protected areas,

The susceptibility to negative consequences of worldwide warming, encompassing both variation in temperatures and extremes, is known as vulnerability. It depends on interaction to a stressor (climate), how sensitive one's home or way of life is to the tension brought on by that exposure, and the ability to adapt and recover from the effects of that exposure.

*Vulnerability = (Exposure * Sensitivity) – Adaptive Capacity*

Exposure describes the state of humans, dwellings, facilities, manufacturing capacity, and other material human resources situated in locations that are vulnerable to hazards (UNISDR, 2017). The communities in the River Sironko system are exposed to floods, drought. Floods and droughts were examined, graded, evaluated, and normalized to produce the exposure index.

Sensitivity describes the socio-economic or demographic characteristics that can make people susceptible to the negative effects of exposure (Declet-Barreto et

al., 2020). The factors that were considered to assess sensitivity include poverty, vulnerable groups (children, the disabled, and the disabled), reliance on family/friends/relatives for livelihood as well as institutional support, and buildings with walls made of mud and poles. These datasets were obtained from the Uganda Bureau of Statistics (UBOS). These factors were analysed, ranked, weighed, and normalized to produce the sensitivity index.

Adaptive capacity captures the potential of communities to avoid, minimize, or cope with the negative effects of climate exposure. The factors considered include access to information, an alternative source of livelihood, and the wall type. Households that use radios, televisions, telephones, and community announcements were considered to have a higher adaptive capacity because most of the early warning information is relayed using these sources.

These factors were studied, ranked, weighed, and normalized to produce the adaptive capacity index. The exposure, sensitivity, and adaptive capacity indices were analysed in the GIS environment to generate the vulnerability index. The vulnerability index was mapped at the sub-county level.

According to UNDRR (2015), disaster risk is defined as the probability of fatalities, injuries or destruction, and damage from a disaster during each time frame. Disaster risk is commonly understood to be the result of a hazard's interaction with the features that expose and make people and places vulnerable.

*Risk = Hazard * Exposure * Vulnerability*

The multi-hazards that were considered in this assessment (drought, floods) were combined, weighed, and normalized to produce the hazard index. The population

of the communities in the River Sironko ecosystem were considered the exposed element. The population was ranked and normalized to produce the exposure index.

The hazard, exposure, and vulnerability indices were analysed and normalized according to the above equation to produce the risk index. The risk index was mapped at a sub-county level in the Sironko and Bulambuli districts

CHAPTER FOUR: RESULTS

4.1. To Examine the Spatial Extent of Forest Ecosystem Degradation in Sironko and Bulambuli districts between 2000 and 2023

To examine the spatial extent of forest ecosystem degradation in Sironko and Bulambuli districts between 2000 and 2023, the assembled data sets were manipulated using GIS tools to obtain the required results. The results are represented in form of maps and tables.

4.1.0 Land cover maps and predictions

The land cover maps obtained from the classification of 2000, 2023 and 2040. Landsat imagery had eight classes which included: Built-up areas, bush lands, forests, grasslands, farming, Tree plantation, wetlands and woodlands.

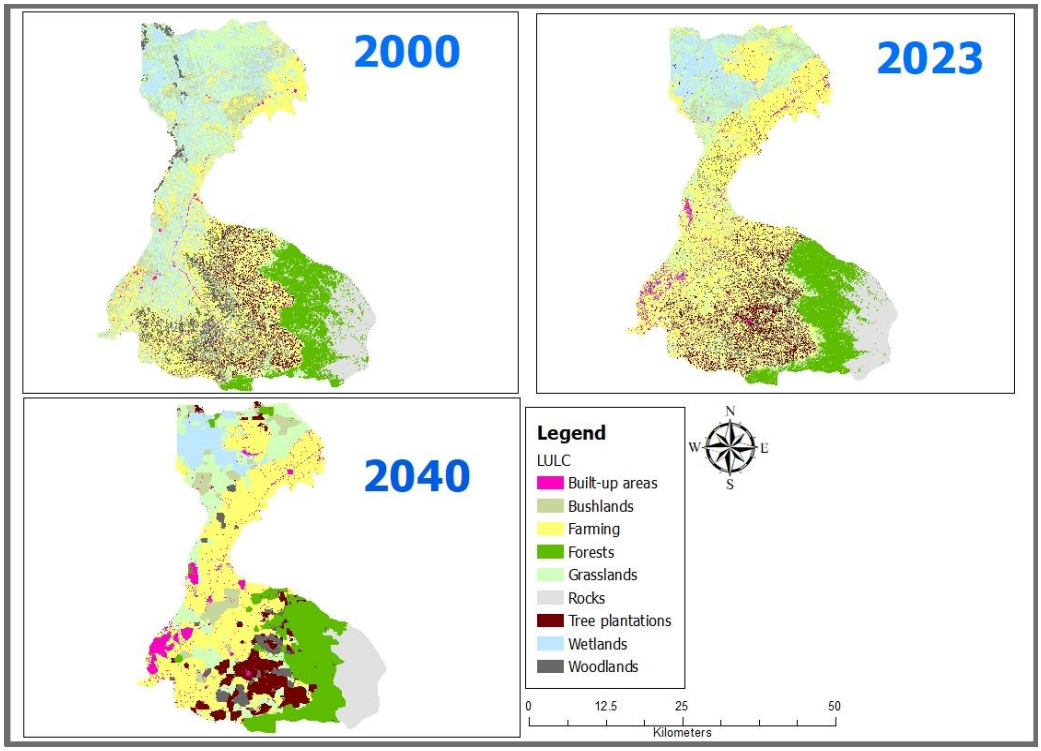

Figure 4.1: Past, Current, and projected land use/cover distribution in Bulambuli and Sironko

4.1.1 Past, Current, and projected land use/cover statistical changes

The image classification indicated that in 2000, crop farming (28.2%), wetlands (16.6%), and grasslands (15.5%) were the three most predominant land-use/cover types (LULC) followed by forests (11.3%), bush lands (10.2%) and rocks (7.3%). Built-up areas (0.7%), tree plantations (3.9%), and woodlands (6.5%) were considered the least predominant land use/cover.

By the year 2023, crop farming (37.5%) was the most predominant land-use/cover type followed by grasslands (14.3%) and forests (12.9%) (Table 4.1). While Wetlands (7.9%), Rocks (7.7%), Tree plantations (7.3%), Bushland (6.5%), Woodlands (3.5%), and Built-up areas (2.4%) covered the least area.

In all the studied periods, built-up areas, farmland, forests, and tree plantations significantly increased at the expense of bushlands, grassland, wetlands, and woodlands coverage, in which the bushlands, grassland, wetlands, and woodlands decreased by 10.2% to 6.5%, 15.5% to 14.3%, 6.5% to 3.5% from 2000 to 2023 respectively. This study clearly showed that land use types (built-up areas, farmland, and tree plantations) were high on the increase compared to land cover types in both Sironko and Bulambuli districts.

The projected land use/land cover types of 2040 were computed using the CA-Markov model as presented in Figure 4.1, whilst their area is given in Table 4.1. The area of bushlands, grasslands, wetlands, and woodlands is assumed to decrease from 6.5%, 14.3%, 7.9%, and 3.5% in 2022 to 3.6%, 13.1%, 6.4%, and 3.2% in 2040 respectively.

A continuous increase in farmland (40.4%), built-up areas (4.1%), forests (13.9%), and tree plantations (7.9%) will be observed in 2040 (Figure 4.1). In

addition, the expansion of farmland and settlement will be expected to increase at the expense of bushlands, grasslands, wetlands, and woodlands.

Table 4. 1: Past, Current, and projected land use/cover statistical changes

Land use/cover types	2000		2023		Prediction 2040	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Built-up areas	750	0.7	2637	2.4	4551	4.1
Bushland	11208	10.2	7186	6.5	4000	3.6
Farming	30975	28.2	41190	37.5	44439	40.4
Forest	12381	11.3	14177	12.9	15267	13.9
Grassland	17012	15.5	15701	14.3	14429	13.1
Rocks	8001	7.3	8412	7.7	8076	7.3
Tree plantations	4245	3.9	8062	7.3	8696	7.9
Wetlands	18236	16.6	8696	7.9	7008	6.4
Woodlands	7155	6.5	3900	3.5	3497	3.3

The increase in forested areas was attributed to restoration interventions implemented by the local communities and government, while the reduction in wetland cover was reported by the key informants to be a result of rice growing, deforestation, burning and unclear land tenure

4.1.2 Land use/cover loss and gains in Sironko- Bulambuli districts

Based on the results presented in sections 4.1.0 and 4.1.1, the areas in hectares occupied by the different land cover classes over the different years were computed to identify what land use/cover gained and lost. Results are as shown in table 4.2 below.

Table 4. 2: Land use/cover loss and gains in Sironko- Bulambuli districts

	Changes (2000-2023)		Changes (2023-2040)	
Landuse/cover	**Area (Ha)**	**%**	**Area (Ha)**	**%**
Built-up areas	1887	1.7	1914	1.7
Bushland	-4022	-3.7	-3186	-2.9
Farming	10215	9.3	3249	3.0
Forest	1796	1.6	1090	1.0
Grassland	-1311	-1.2	-1272	-1.2
Rocks	411	0.4	-337	-0.3
Tree plantations	3817	3.5	634	0.6
Wetlands	-9539	-8.7	-1689	-1.5
Woodlands	-3254	-3.0	-403	-0.4

4.1.3 Accuracy Assessment

Accuracy requirements were achieved in all images which, supports the analysis of effective remote sensing (Herold et al., 2005).

Table 4.3: Accuracy Assessment for land use/cover maps

Sensor	Acquisition date	Classified image	Over accuracy (%)	Kappa Statistics (%)
Landsat 7 ETM	19/01/2000	2000	86.6	85.4
Landsat 8(S-2)	03/01/2023	2023	92.2	90

4.1.4 Extent of Forest ecosystems degradation

The classification of forest degradation was done at sub country level. According to both satellite imageries and field data, Bulambuli district, in Bunambutye,

Masiira, and Buluganya sub-counties were characterized by the highest forest degradation followed by Bulaago, Bumasobo, Lusha, and Bumugibole sub-counties. In the Sironko district, Buteza, Buyobo, Bunyafa, and Buhugu sub-counties had the highest degraded forests followed by Bumasifwa, Budadiri Town Council, Bugitimwa, Zesui, and Masaba respectively. As per district, Sironko had the most degraded forests against the intact part which was contrary to Bulambuli where the degraded park was less than the intact one.

The above sub counties were among the populated ones and most of them border Mt Elgon National Park. This might be to the availability of land for agriculture, settlements and the richness of the areas in ecosystem services supplies which contribute to forest degradation.

Table 4. 4: Forest degradation statistics in Sironko and Bulambuli districts

Districts	Sub counties	Forest	Degraded (Ha)	%	Intact (Ha)	%	Grand Total (Ha)
Bulambuli	Bulaago	Mt Elgon	1724.8	43.2	2266.8	56.8	3991.6
	Buluganya	Mt Elgon	255.1	45.3	307.6	54.7	562.7
	Bumasobo	Mt Elgon	3035.6	42.2	4154.3	57.8	7189.9
	Bumugibole	Mt Elgon	826.4	33.5	1639.0	66.5	2465.4
	Bunambutye	Pian-up, Sebei, kaptokoi	85.7	100.0	0.0	0.0	85.8
	Lusha	Mt Elgon	14.2	40.9	20.5	59.1	34.7
	Masiira	Sebei, Mt Elgon	1887.9	45.8	2230.8	54.2	4118.7
Sironko	Budadiri Town Council	Nakiwondwe	4.7	56.7	3.6	43.3	8.2
	Bugitimwa	Mt Elgon	1825.7	55.5	1461.0	44.5	3286.7
	Buhugu	Mutufu	9.5	73.8	3.4	26.2	12.9
	Bumasifwa	Mt Elgon	19.3	69.1	8.6	30.9	28.0
	Bunyafa	Mt Elgon	73.5	74.8	24.7	25.2	98.2
	Buteza	Mt Elgon	4.3	83.9	0.8	16.1	5.1
	Buyobo	Mutufu	2.6	79.1	0.7	20.9	3.3
	Masaba	Mt Elgon	220.1	23.1	734.7	76.9	954.9
	Zesui	Mt Elgon	389.6	26.2	1095.2	73.8	1484.9

4.2 To Establish the Drivers of Forest Degradation and Forest Ecosystem Services In Sironko and Bulambuli Districts

4.2.1 Characteristics of Household Respondents

Socio-economic demographics

Different activities below are forces behind drivers of forest and ecosystem services degradation. The respondents were selected from two districts (Table 4.5). The proportion of respondent representation is based on the total number of households in the two districts. Sironko District (56%) had the highest proportion of respondents compared to Bulambuli District (44%). A large proportion (60%)

of the respondents who participated in the household survey were household heads. A third were spouses while the other categories collectively form 9% of the relationship to the household head.

A large proportion (66%) of the respondents interviewed were males. Overall, the mean age of the respondents in the two districts was 46 years. A majority (79%) of the respondents fall under the age category of 18-59 years. Such evidence reveals that most of the respondents belong to a productive age that can potentially and actively participate in productive activities.

The majority (74%) of the respondents indicated they were married. 25% of the respondents had an ordinary level but an incomplete level of education and below. Only 13% completed ordinary level education and only 13% were educated above ordinary level secondary school education advanced level incomplete, advanced level complete, diploma, university degree, and specialized training or vocational training.

Households in the study area depended on eight (8) sources of income. Of those, the main sources of income were agriculturally based, dominated by crop farming (57%) and livestock keeping (11%) largely at the subsistence level. The non-agricultural-based sources of income were dominated by salary employment reported by 12% of the respondents, followed by self-employment.

Table 4. 5: Socio-economic demographic characteristics of respondents

Variables	**Districts**					
Gender	**Bulambuli**		**Sironko**		**Total**	
	N	%	N	%	N	%
Male	76	62	106	68	182	66
Female	47	38	49	32	96	34
Age Category						
18-20	3	2	2	1	5	2
21 – 29	14	11	11	8	25	9
30 – 39	34	28	41	26	75	27
40 – 49	27	22	37	23	64	23
50 – 59	17	14	32	21	49	18
60 – 69	17	14	20	13	37	13
70 +	11	9	12	8	23	8
Education Level						
No formal education	18	15	14	9	32	12
Primary level complete	42	34	60	39	102	37
Ordinary level incomplete	27	22	44	28	71	25
Ordinary level complete	17	14	19	12	36	13
Advanced level incomplete	2	2	4	3	6	3
Advanced level complete	3	2	1	1	4	1
Diploma	8	6	7	4	15	6
University degree	3	2	1	1	4	1
Post-graduate	2	2	2	1	4	1
Specialized/Vocational training	1	1	3	2	4	1
Sources of livelihood						
Agriculturally based						
Crop farming (subsistence less than 10 acres cultivated)	78	64	85	54	163	57
Livestock farming Subsistence (<20 cattle)	10	8	20	13	30	11
Crop farming commercial (above 10 acres)	5	4	15	10	20	7.5
Livestock commercial (more than 10 heads of cattle)	3	2	4	3	7	2
Fishing activities/Fish farming	1	1	0	0	1	0.5
Non-Agricultural based						
Salary	16	13	16	10	32	12
Self-employment	4	3	13	8	17	7
Personal Services	6	5	2	1	8	3

Household Access to Land

Outcomes of the survey demonstrate that most (70%) households had access to land, and only a third 30% indicated the contrary. On average, households had

access to 2.7 acres of land. Data by the district suggested that households in Sironko had more land at least 2.9 acres compared to those in Bulambuli with an average size of land of 2.4 acres.

Additionally, of the total accessed by the households, a majority (70%) of it, which was 1.9 acres, were under productive use. Data by the district suggested that households in Sironko had more land under productive use (2 acres) compared to those in Bulambuli with 1.7 acres of land under productive use.

The major economic activity was cropping farming, accounting for 99% of the responses followed by animal rearing accounting for 21% of the response, and thirdly poultry rearing accounted for 18% of the responses.

The main six grown crops were coffee, maize, banana, beans, and vegetables. This followed by the cultivation of Irish potatoes, cassava, groundnuts, sunflowers, and peas. Households in the study area kept some livestock. The percentage distribution of livestock kept expresses that most households preferred to keep mainly small livestock Goats (47%), partly due to scarcity of land and indigenous cattle (38%) among others.

Household Sources of Energy

The results suggested that households in the project area were accustomed to using several energy sources (Table 4.6). Almost all (62%) of respondents indicated firewood as the main source of energy followed by charcoal (20%) and grass (9%). Both firewood and charcoal were got from the forest.

Table 4. 6: Household source of energy

Sources	Bulambuli		Sironko		Total	
	N	%	N	%	N	%
Firewood	75	61	94	61	169	61
Charcoal	27	22	31	20	58	20
Grass	10	8	15	10	25	9
Solar	3	2	5	3	8	3
Electricity	2	2	3	2	5	2
Processed gas	4	3	1	1	5	2
Paraffin	0	0	4	2	4	1
Crop residues	2	2	0	0	2	1

4.2.2 Drivers of forest degradation and forest ecosystem services in Sironko and Bulambuli districts

Rapid population growth (31%), agriculture intensification (29%), low employment opportunities (35%), expansion of land for settlement (11%) were noted to be the major drivers of forest and ecosystems degradation. Poor governance and management of ecosystems (5%), floods and drought (5%) and Poverty (4%) were among the growing issues. Lack of alternative livelihoods and Illiteracy were observed. According to correspondents, all above drivers had no impact in the past but contributed to the challenges forests were facing. This implied that institutions responsible should continue implementing forest restoration in river Sironko ecosystem. Community mobilization and education that protect natural resources in general like forests and wetlands were encouraged.

Table 4. 7: Drivers of forest degradation

Drivers of forest degradation	N	%
Rapid population growth	87	31
Agricultural intensification	80	29
Low employment opportunities	35	13
Expansion of land for settlement	30	11
Floods and drought	15	5
Poor governance and management of ecosystems	13	5
Poverty	12	4
Illiteracy	4	1
Lack of alternative livelihoods	2	1

4.3. To Determine the Changes in the Ecosystem Services in Sironko and Bulambuli Districts

4.3.1 The ecosystem services derived from forest ecosystems in Sironko and Bulambuli

As reflected by informants, provisioning services (the source of food 9%, fuel wood 14.4%, Source of pastures 6% and building material 5.4%) was the dominant ecosystem service that respondents highlighted. Regulating services through reducing floods and drought was well known by the locals. Cultural services (sense of belonging 32% and spiritual site 25%) were highlighted as the most used by informants in Bulambuli and Sironko (Table 4.8)

Table 4. 8: Ecosystem services and supplies from forest ecosystems

Services/Supplies	N	%
Sense of belonging	88	32
Spiritual sites	70	25
Source of fuel wood	40	14.4
Source of food (e.g., fruits, nuts, mushrooms, honey and spices)	26	9
Source of pastures (for cattle, goats, sheep, etc.)	17	6
Source of building materials	15	5.4
Reduces the impact of floods and drought	11	4
Source of medicinal plants	9	3.2
Raw materials for industrial products	2	1

Respondents noted the lost important supplies included natural pest controllers, and the ability to reduce the impact of floods and drought that were experienced in the past decades but were no longer 2023. Most of the communities were farmers and pest control was critical issue in agriculture. If precaution measures and forest mitigation steps were not considered in all areas, climate change and extreme events like floods and drought might be observed in future.

4.3.2 Drought and floods

4.3.2.1 Drought

The results in Table 4.9 signify that district level, Bulambuli had the lowest intensity (640 Ha) whereas Sironko presented zero percent high drought hazard intensity. Sironko district had the highest drought hazard of intensity compared to Bulambuli. The high-altitude mountainous area experienced low drought

hazard, the mid-altitude zone experienced moderate drought whereas the low-land area experienced high drought hazard intensity (Figure 4.5). The high drought hazard was experienced in Bulambuli district in the Bunambutye, Bwikhonge, and Nabbongo sub-counties.

Table 4. 9: Coverage of drought hazard in Bulambuli and Sironko districts

District	Bulambuli		Sironko		Total	
Intensity	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Very Low	640	1	3,880	9.6	4,520	4.1
Low	25,000	36	17,830	44.1	42,830	39.1
Moderate	7,250	11	18,730	46.3	25,980	23.7
High	36,130	52	0	0	36,130	33
Total	69,020	100	40,440	100	109,460	100

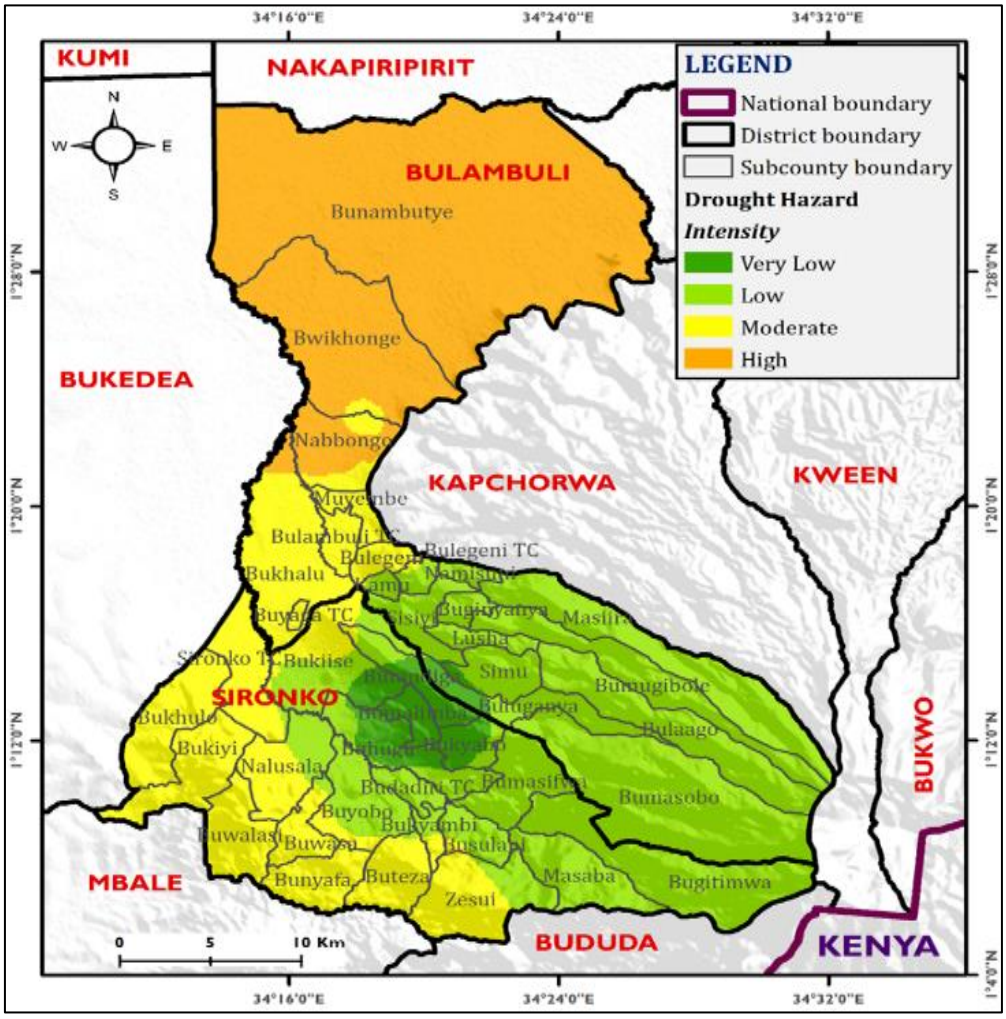

Figure 4. 2: Drought hazard in Bulambuli and Sironko districts

4.3.2.2 Flood

As per flood coverage, the biggest area exposed to high flood hazard intensity was found in Bulambuli district (41.7%) (Figure 4.3). Bulambuli district, the sub-counties mostly exposed to floods included Bunambutye, Bwikhonge, and Bukhalu. In the Sironko district, the sub-counties mostly exposed to floods included Sironko Town Council, Bukiise, and Buhugu. The biggest portions of the respective flood hazard intensities were found in the Bulambuli district (Table 4.10).

Table 4. 10: Coverage of flood hazards in Bulambuli and Sironko districts

District	Bulambuli		Sironko		Total	
Intensity	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Low	3,570	5.2	240	0.6	3,810	9.7
Moderate	1,610	2.3	460	1.1	2,070	5.3
High	220	0.3	90	0.2	310	0.8
Very high	28,940	41.7	4,150	10.2	33,090	84.2
Total	34,350	49.5	4,940	12.2	39,290	100

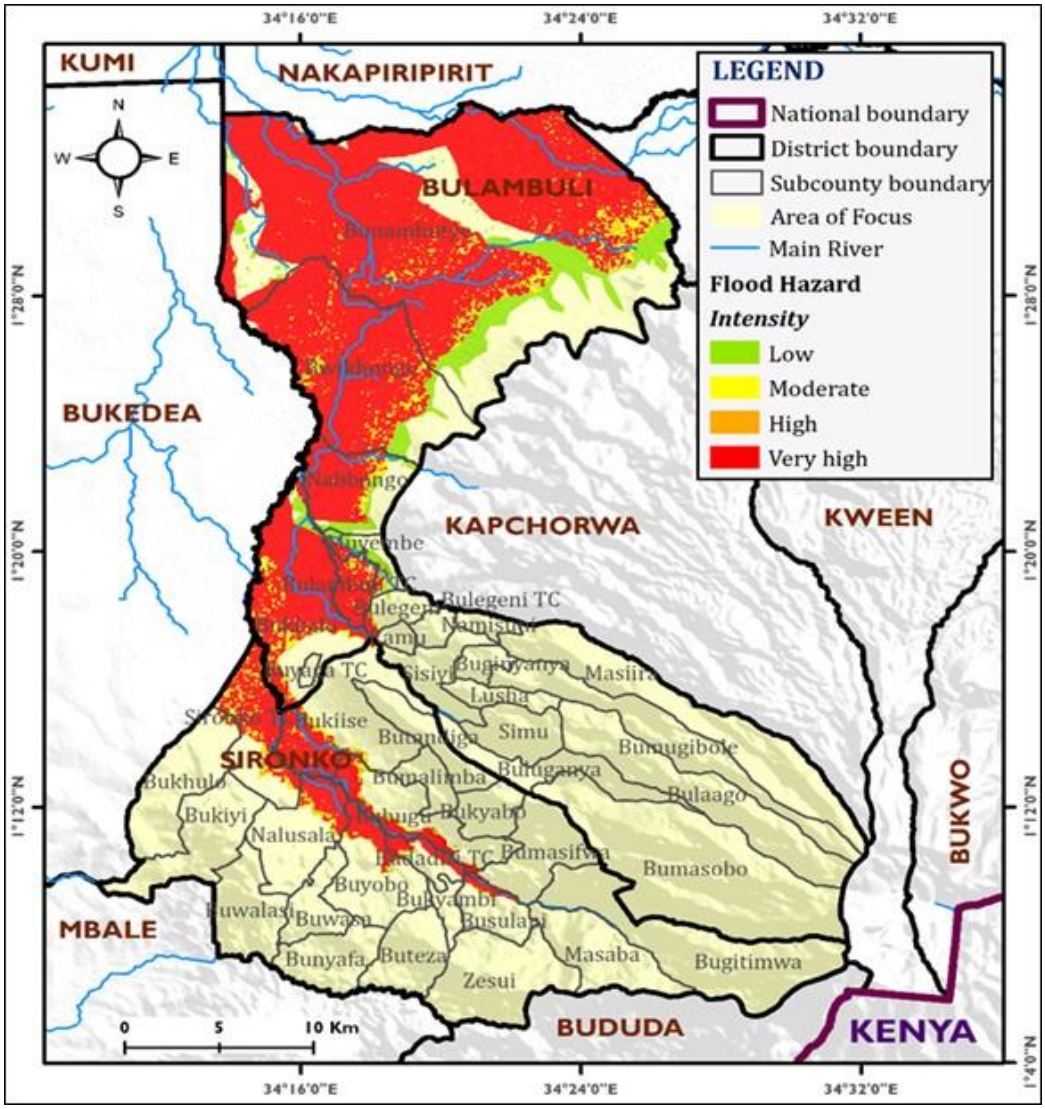

Figure 4. 3: Flood hazard in Bulambuli and Sironko districts

4.3.3 Ecosystem supplies change in Sironko and Bulambuli.

During the field, study respondents highlighted the effects of forest degradation and how they affected their day-to-day life. The most supplies included soil fertility (20.1%), and Source of food (18%). Ability to reduce floods and droughts which falls under regulating services were affected by hazards (14.7%). Spiritual sites and Sense of belonging were not spared from the impacts as seen in the table below. This implied that forests should be a priority for the environmental conservation for all stakeholders to prevent the climate risk in the study area.

Table 4. 11: Ecosystem supplies affected by forest degradation

Ecosystem supplies	N	%
Soil fertility	56	20.1
Source of food (e.g., fruits, nuts, mushrooms, honey, or spices)	50	18
Source of medicinal plants	40	14.4
Source of pastures (for cattle, goats, sheep, etc.)	30	10.8
Ability to reduce the impact of floods and drought	41	14.7
Spiritual sites	28	10.1
Sense of belonging	33	11.9

Supplies from Provisioning services were the most affected by forest degradation followed by cultural services and regulating services.

Locals and local government authorities were optimistic that the future would be different because of the technology in agriculture like drought resistance crops that were being introduced in many districts. However, if this was not made available at no cost for the farmers, it might not be prevented from happening. Additionally, technology should be environmentally friendly to protect the native environment. Key informants also noted the increased prices of commodities and Crop failure due to drought had never been experienced in the past. The occurrence of the two impacts might be continuous if environmental protection is not embraced in the area**.**

4.3.4 Vulnerability analysis of ecosystem services to floods and drought

The sector-based vulnerability was performed for 3 sectors and this included agriculture, social, tourism. This was because of the ecosystem services they

contained. The services included Regulating services (flood and draught impact prevention/reduction) provisioning (quality of soil/ crop land), culture (sense of belonging and spiritual sites). As for social vulnerability, the reason was to show how everything comes back to human beings and how much they depended on nature for survival.

Tourism sector

The vulnerability of the tourism sector to hazards (floods and drought) in the River Sironko ecosystem was run for the forest protected areas. This was because forests play a vital role in the locals' culture. Respondents during the interview highlighted how forests were both spiritual and physical in a sense that they felt more home and a place of mind renewal connecting to their gods.

Sub counties where forests degradation was intense, suffered allot from floods and drought. They could not get resources like medicine, fruits, and mushrooms from the forests anymore.

The assessment showed that about 22,892 hectares of protected areas (94.6%) were slightly vulnerable to drought whereas 1,316 hectares (5.4%) were highly vulnerable to this hazard. Most of the protected areas that were highly vulnerable to drought were in the Sironko district (93.5%) (Figure 4.4). The key hotspots were in Zesui (86.8%), Bunyafa (6.5%), and Buteza (0.2%) sub-counties in the Sironko district as well as Bunambutye sub-county (6.5%) in Bulambuli district.

The protected that were vulnerable to high drought hazards were Namatale CFR, Kaptokoi LFR, and a section of Mt. Elgon NP. For floods, the biggest percentage of the protected areas (99.5%) were not vulnerable to this hazard. However, some of the protected areas were slightly vulnerable to floods (0.4%) and others were

highly vulnerable to this hazard (0.1%). The protected areas that were highly vulnerable to floods were in the sub-counties of Buhugu (37.7%), Budadiri Town Council (33.6%), and Buyobo (28.7%), in the Sironko district. These forests include Mutufu and Nakiwondwe Local Forest Reserves.

The analysis also showed that about 94.6% of protected areas were highly vulnerable to landslides whereas 5.4% are slightly vulnerable to this hazard. Key hotspots were found in the sub-counties of Bumasobo (30.2%), Bulaago (16.7%), Masiira (15.8%), Bugitimwa (13.3%), and Bumugibole (10.4%).

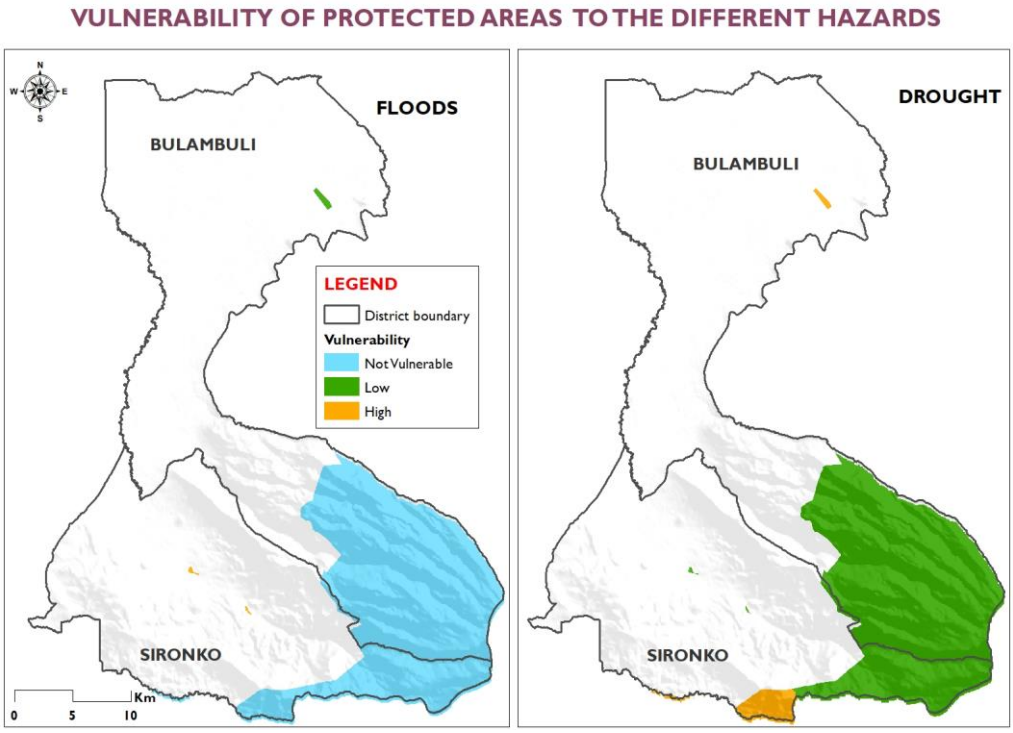

Figure 4. 4: Vulnerability of protected areas to floods and droughts in the river Sironko ecosystem

Agriculture sector

The vulnerability of the agriculture sector to hazards (floods and drought) in the river Sironko ecosystem was performed for the croplands and livestock.

The agricultural sector in both Sironko and Bulambuli districts is highly sensitive to floods and drought. About 70% of the croplands are highly vulnerable to drought whereas 30% of croplands are slightly vulnerable to drought. Most croplands that were highly vulnerable to drought were in Bulambuli district in the sub-counties of Bunambutye (37.3%), Bwikhonge (10.7%), Bukhalu (9.4%), and Nabbongo (6%).

The croplands that were slightly vulnerable to drought were in the high-altitude areas of Mt. Elgon (Figure 4.5). For floods, 26% of croplands were highly vulnerable, 16% were slightly vulnerable whereas 58% of croplands were not vulnerable to floods. Most of the highly vulnerable croplands to floods were in Bulambuli district (79%) in the sub-counties of Bunambutye (31.9%), Bukhalu (16.9%), Bwikhonge (16.2%) and Nabbongo (8.8%). The croplands that were highly vulnerable to floods were in low-lying areas (Figure 14). In this ecosystem, 30% of the croplands were highly vulnerable to landslides whereas 70% were slightly vulnerable to this hazard.

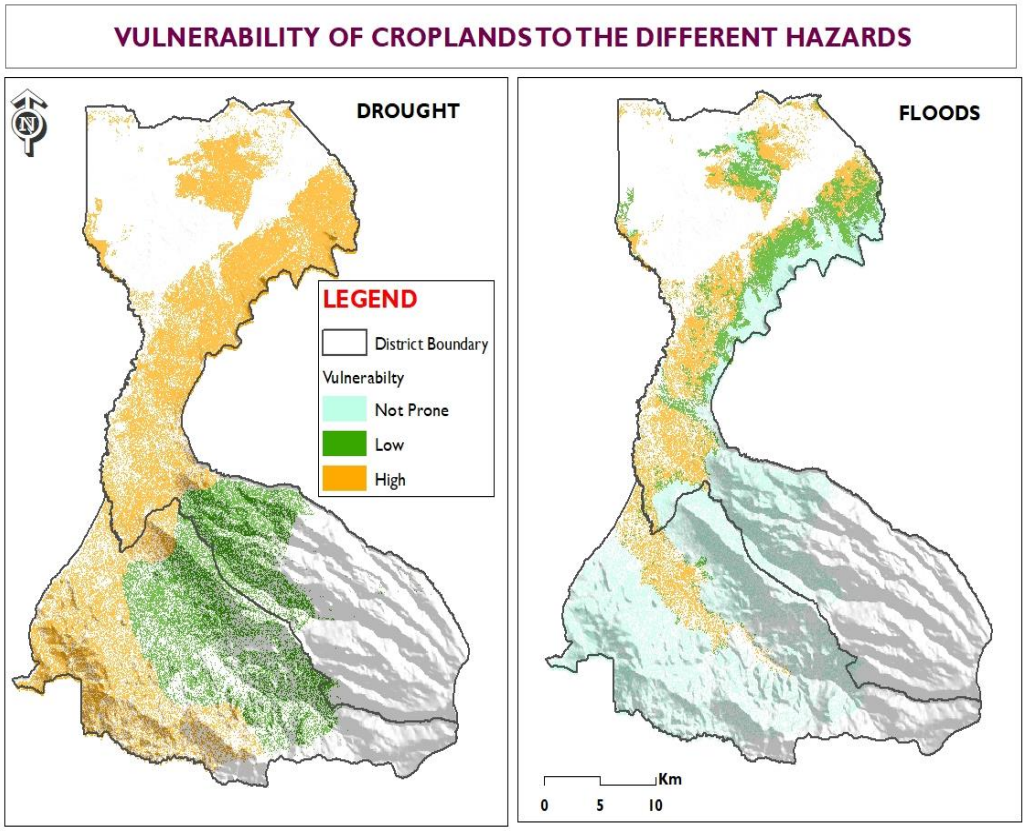

Figure 4.5: Vulnerability of croplands to different hazards in the river Sironko ecosystem

Social sector

The vulnerability of the social sector to hazards (floods and drought) in the River Sironko ecosystem was run for the population. The assessment showed that about 166,653 people (42%) were highly vulnerable to drought whereas a total of 230,347 people (58%) was slightly vulnerable to the same hazard. The sub-counties that had the biggest percentages of people vulnerable to drought included Bukhalu, Muyembe, and Nabbongo sub-counties in Bulambuli district as well as Bukhulo sub-county in Sironko district, all having 100% vulnerability (Figure 4.6).

The sub-counties that had the biggest number of children that were highly vulnerable to drought were Bukhalu (5,315), Bukhulo (3,395), Sironko Town Council (2,796), Buwalasi (2,215), and Bukiyi (2,146). The biggest number of

elderly people that were highly vulnerable to drought were found in the sub-counties of Bukhalu (1,289), Buwalasi (1,066), Bukhulo (994), Bukiyi (881), and Bunyafa (772).

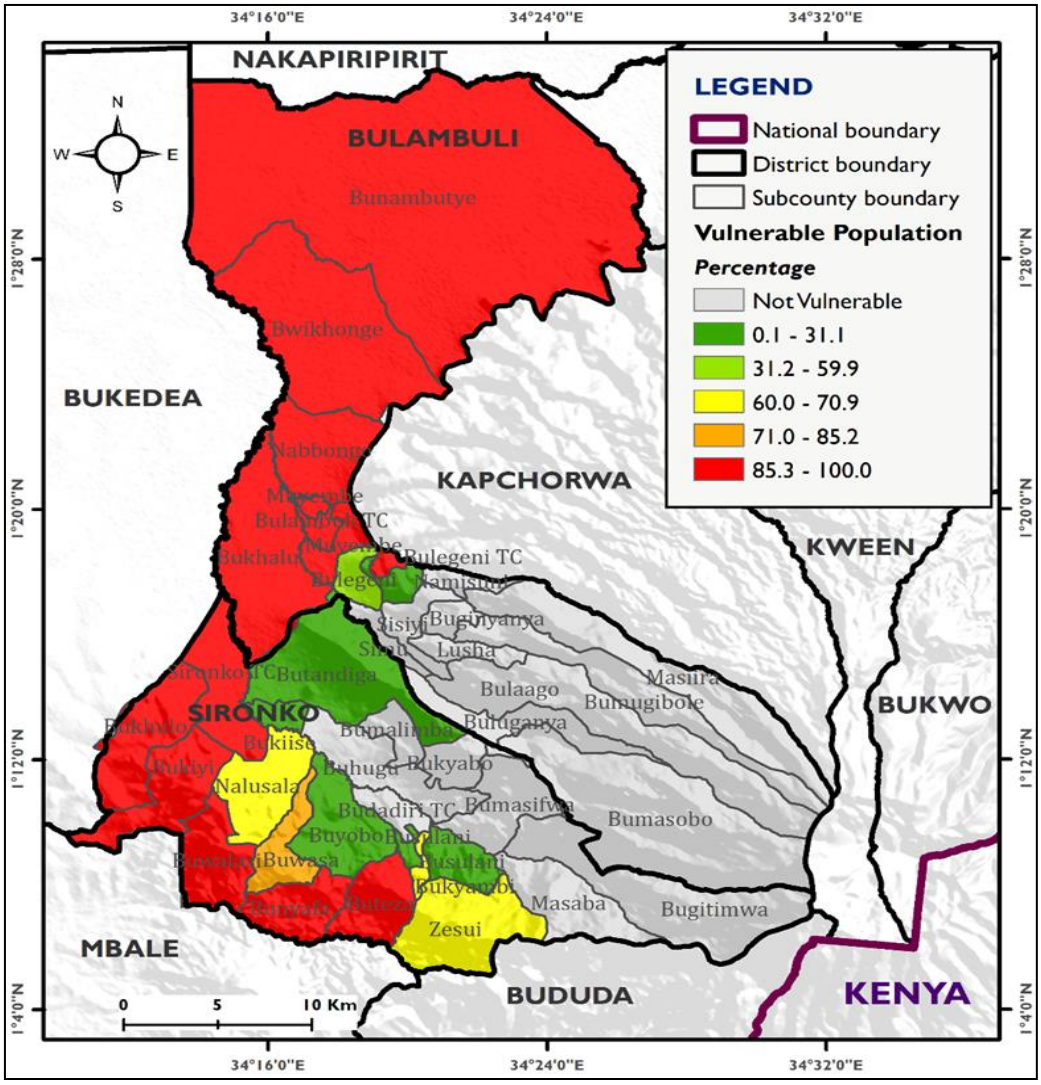

Figure 4.6: Percentage of the population vulnerable to drought hazards in the river Sironko ecosystem

Analysis showed that about 88,012 people (22.2%) were highly vulnerable to floods whereas 7,818 people (2%) were slightly vulnerable to this hazard. However, a population of 301,170 (75.9%) were not vulnerable to floods in the river Sironko ecosystem. Most of the people that were highly vulnerable to floods were found in the Bulambuli district (Figure 4.7). The sub-counties that had the

biggest population vulnerable to floods include Bukiise (99.2%) in the Sironko district, Bulambuli Town Council (90.8%), Bwikhonge (83.1%), Bukhalu (74.2%), and Bunambutye (68.9%), in Bulambuli district.

Most of the children that were highly vulnerable to floods were found in the sub-counties of Bukhalu (3,944), Bukiise (3,520), Sironko Town Council (1,882), Bwikhonge (1,281), and Nabbongo(1,123). Most of the elderly people that were highly vulnerable to floods were in the sub-counties of Bukiise (1,385), Bukhalu (956), Sironko Town Council (449), and Bunambutye (342).

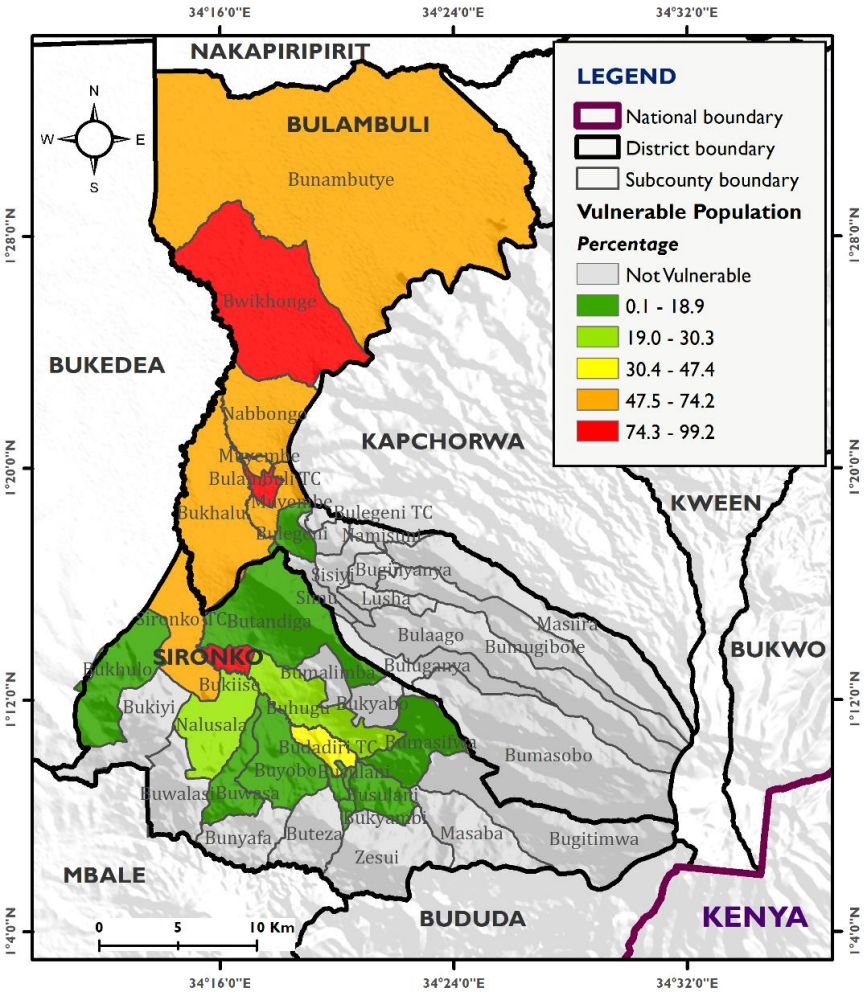

Figure 4.7: Percentage of the population vulnerable to floods in the river Sironko ecosystem

CHAPTER FIVE: DISCUSSION

5.1 The spatial extent of forest ecosystem degradation in Sironko and Bulambuli districts between 2000 and 2023.

Seven land use/cover classes were mapped and described in the current study based on area coverage. The findings showed alterations in the plotted land use and cover during the reference period. Compared to land use types, which had positive changes, land cover primarily underwent negative changes. A significant increase in the LULC was observed in farming, forests, tree plantation, and built-up areas expanded by the same coverage within the two periods (2000-2023 and 2023-2040). This study clearly showed that land use types (built-up areas, farmland, and tree plantations) were high on the increase compared to other land cover types in both Sironko and Bulambuli districts. The results are consistent with those of Zziwa (2011), who used imagery from satellites to analyse shifting how land was used and covered and found that between 1985/86 and 2015, Uganda's built-up farmland increased by 4.2% and 3.5%, respectively, mostly at the cost of undeveloped land like jungles and steep mountains.

According to both spatial data analyzed (GIS), and respondents indicated that built-up areas and farmland increase was not new in the study area. Population growth came with the need for more land for settlement and agriculture. This was one of the causes of degradation of forests, wetlands, grass land and woodland in the study area. According to informant, the farmland and build up increase were more accelerated from 2010. Similarly, to this, Majaliwa et al. (2018) discovered that in their analysis of the scope of past, current, and future land use schemes in

Uganda, livelihood farming has experienced the most expansion in land among all the land use schemes.

On the contrary, bushland, wetlands, and woodlands were converted to other land use and others like some wetlands lost more than half of the area coverage between 2000 to 2023. The rate at which the above land uses have lost coverage from 2000 to 2023(10.2 to 6.5 %, 16.6 to 3.5% and 6.5 to 3.5% respectively) was alarming. According to the CA-Markov model as presented in Figure 4.1, whilst their area is given in Table 4.1, The same loss would be observed in 2040 when bushland, wetlands, and woodlands could be converted to other LULCs mostly, agriculture and built-ups. To minimize or eradicate effects land use on both ecosystems and people dependent on ecosystem values the study called for more environmental conservation steps to avoid a rough future. This is in line with a study by Guo et al., (2021) where he concluded land use like wetland, wood land was converted to other land use which affected the ecosystem services. He also noted that if measures are not put in place to deal with the impacts, more natural disasters would be unavoidable. Similary to Zziwa (2011), The proportion of grassland expansion was slower than the speed at which grassland cover declined to various land uses and cover categories. The woodland, grassland and wetlands might be on the verge of disappearing if no conservation measures are instituted to protect them. Additionally, in his paper on modelling the impact of land use/cover changes on water balance of River Mitano catchment in Southwestern Uganda, Barasa et al., (2023) concluded that between 2000 and 2020, there was a significant increase in cropland (6.8%) and built-up areas (3.0%) at the expense of grasslands and wetlands.

The increase in Tree plantations is new in the area, according to respondents. It was part of ecosystem restoration effort that government and private sectors were putting in place to minimize the forest degradation of Mt Elgon and other ecosystems live wetlands. However, Mt Elgon was the only forest being restored yet others like Pian-up, Sebei, kaptokoi were almost completely degraded and yet there was no effort made to restore them. In a tree plantation, stakeholders were given other sources of income generation to reduce stress on ecosystems in river Sironko including pee keeping, fishponds, even money for planting trees. Findings contradict with Kusiima et al., (2022). Guo et al., (2021), contradict the finding by rejecting the increase in forest cover. According to Opedes et al., (2022), there was a significant reduction of tropical high forest in the Mt Elgon region between 1978 and 2020.

As per district, Bulambuli districts had less forests degradation compared to Sironko district. This was because Bulambuli district is less populated compared to Sironko. The were many factors influencing the distribution of forest extend. Some are discussed below (5.2). Although the latter study was conducted on a national spatial scale, the results of this study are consistent with those of Kiggundu et al. (2018) and Majalwa et al. (2018).

Kusiima et al. (2022) used supervised image classification of Landsat imagery for 1990, 2000, 2010, and 2020 to assess spatiotemporal trends in land use land cover alterations in the Budongo-Bugoma landscape. They also used the Dinamica-EGO modeling platform to predict the LULC situation in 2040. The study found that between 1990 and 2020, grassland, commercial farmland, and built-up areas saw an increase. which is consistent with the study's conclusions.

Other projects were being done in the study area including Ecosystem Based Adaptation (EBA) in Forest and Wetlands ecosystems. The project is being implemented in four wetland and forest systems of Rwizi-Mburo-Nakivale, Rwambu-Mpanga, River Enyau and Sironko. There is hope for more tree plantations and ecosystem restorations in future if the interventions continue.

5.2 The drivers of forest degradation and forest ecosystem services in Sironko and Bulambuli districts

The assessment was done through ground truthing, group discussion and interviews with multiple stakeholders including farmers, local councils, district environmental and forestry officials, teachers, community elders and students.

Rapid population growth, agriculture intensification, low employment opportunities, expansion of land for settlement were noted to be the major drivers of forest and ecosystems degradation. Poor governance and management of ecosystems, climate change impacts, Poverty, Lack of alternative livelihoods and Illiteracy were among the growing issues.

Services from ecosystems and the jungle environment shortfall is the primary cause of the ecosystem deficit in the River Sironko was the clearance of land for farming and settlement by increasing numbers of people on small, average 2 ha of land. The loss of forest in Mt. Elgon areas as well as other forested areas is probably going to continue to be explained by this tendency. Estimates of human density are also startling; the nation's national average is 102 people/km2, while the global average is 42 people/km2 (Mwinike, 2021). Land area on the other hand has remained static; thus, forests and wetlands with productive land will continue being utilized for agriculture to meet the needs of people. Kiggundu et

al. (2018) credited enormous land use and land cover transformations in Murchison Bay catchment over the last three decades (1984-2015) to quick population expansion and urbanization while kizza et al., (2017) concluded the same in highland ecosystems of Lake Bunyonyi Catchment in western Uganda which inline of study the findings.

Crop farming was the dominant source of livelihood in Sironko ecosystem. When the respondents were asked why they preferred to cultivate nearby forests they indicated the need for fertile land to curry out gardening since there were low employment opportunities even for those who studied. This is in accord with the findings by Msofe et al. (2019), They saw an increase in activity by people aimed at increasing farmland in order to guarantee availability of food and boost revenue of growing populations. According to Pomeroy et al. (2015), agricultural output must increase to meet the growing population's food needs, yet doing so comes at the price of natural vegetation cover. Instead of intensification and increasing production, which is generally quite low, this has been accomplished by expanding the areas used for crops. who observed that intensification of human activities seeking to ensure food security and improve on income of the growing population by expanding farmland. According to Pomeroy et al. (2015), crop output must increase to meet the growing humanity's dietary requirements, yet doing so comes at the price of natural forest cover. Instead of deepening and increasing production, which is generally quite low, this has been accomplished by expanding the areas used for crops. Dosdogru et al., (2020) noted that Nature is under significant problems due to rising numbers of people, growing cities, and other human-induced changes. These activities are adversely affecting ecological services that serve as a protective barrier against natural dangers**.**

Coupled with poor governance and management of ecosystems, one of the key drivers of forest ecosystems and ecosystem degradation in River Sironko was wood and timber harvesting. It was the dominant source of energy. These were extracted from the forest ecosystem and hence affected forest cover. This was because of high poverty levels, shortage of other sources of energy like natural gas infrastructure, electricity and the high demand for charcoal both locally and to other areas including Mbale and Kampala which happened to be their big market. It was evident that if there were good governance and management of ecosystems, harvesting wood and timber would have been regulated in all forests. There were very little regulations to prevent degradation in Mt Elgon national park.

Barasa et al. (2022) discovered that Uganda has lost a significant amount of natural plant cover in the refugee settlements and surrounding areas as a result of the tremendous consumption for biomass fuel and lumber in their study on the energy potential of harvested wood fuel by refugees in northern Uganda. The results show that family size, tradition, cooking style, food type, substantial amounts of poverty, and the affordability of family labour were the main refugee decisions that influenced wood-fuel gathering. In his work on biomass extraction and its effects on a protected tropical highland rainforest in Uganda, Sassen et al. (2015) also concur. He said that the demand for fuelwood in the vicinity of Mount Elgon has significant but varied effects across a sizable portion of the park. The park's boundaries suffered from the exploitation of certain tree species as biomass. Nikdel et al., (2010) found that logging really messes up forests, and when timber is taken out without control, it harms the trees that are still standing. Plus, building logging roads opens the door for people to move in and starts

farming for their own needs. This whole deforestation issue isn't just happening around River Sironko; it's a problem in other areas of the region too, as pointed out by Thomas et al., (2015). This does not contradict the literature reviews in this study.

Climate Change Impacts was highlighted by informants as the most growing and pressing driver. Climate change has worsened natural disasters like floods, drought and landslides. Farmlands were affected by the disaster which left locals without a choice but degrading forests for fertile land. Forest invasion made people and animals dependent on ecosystem services vulnerable to hunger and immigration. The study finds are in line with Cao et al. (2016) who examined how human activity and warmer temperatures affected the ecological service value of Inner Mongolia's Xilin Gol League grassland between 1989 and 2011. According to their analysis, between 1989 and 2011, human activity and warming temperatures caused a 26% reduction in the environmental service value. Also, According to Appiagyei et al. (2022), the Mediterranean forest environment's services— timber and non-wood timber goods, water supply, stored carbon, leisure, and tourism—are being negatively impacted by global warming and are expected to be so in the coming decades.

This implies that institutions responsible (NEMA, MWE, UNEP, world bank, NGOs, local Leaders, local government officers and others) should accelerate forest restoration in river Sironko ecosystem. Ecosystems education, alternative sources of livelihood will assist in natural resources protection in general like forests.

5.3 The supplies of ecosystem services in relation to forest degradation in Sironko and Bulambuli districts

Forest degradation and all its secondary effects like floods and drought affected different social groups, ecosystems and crop production. When nature is being damaged or altered, it jeopardizes the future well-being of humans (La Notte et al., 2017) Millennium Ecosystem Assessment, (2005), stated that humanity's wellness relies on habitats. They are not serviced if there are no human benefits (Fisher et al., 2009).

During the field study the effects ecosystem degradation to ecosystem supplies and how they affected their day-to-day life highlighted. The most supplies impacted from the effects of ecosystems degradation like floods and drought included soil fertility. According to the survey, looking at fertile soil was the most reason for farmers encroach on forests and wetlands in river Sironko catchment. Drought caused soil moisture loss and floods washed away soil nutrients thus making crop growth hard, yet agriculture was most important source of livelihood, both for survival and for commercial purposes. Farmers in both districts highlighted the loss of business hence reductions in household incomes and Smallholder growers' inability to afford food due to droughts and floods. Elum et al., (2017); Nsubuga et al., (2018), and Nuwagira et al., (2022) agreed that forest degradation and high downpours which led to drought and floods have affected soil fertility in diverse parts of the country plus Elgon region. The region's farms and animals suffered losses worth US$13 billion due to the drought (FAO, 2018). However, 41 million households were impacted by floods in Latin America and the Caribbean, which resulted in harm worth US$26 billion

(Nuwagira et al., 2022), Barasa et al., (2022) predicted that the future will face similar issues.

Were et al., (2023) documented Crop failure due to drought and Increase in the prices of commodities. Local government authorities were positive that the future will be different because of the technology in agriculture like drought resistance crops that are being introduced in many districts**.** This should be free and environmentally friendly for native environmental protection.

Source of food was another ecosystem supply affected by forest ecosystem degradation many. Respondents acknowledged that fruits, nuts, mushrooms, honey, spices, and medicinal plants gathering were highly affected mostly in forests including Pian-up, Sebei, and kaptokoi where supplies were totally depleted or very hard to get, they have opted to buy what they would get from the forest at no cost. Study in line with Diksha et al., 2024 who noted that forest encroachment affected fruit crops at different phases of growth and development, causing problems like sunburn damage, fruit cracking, inadequate pollination, reduced panicle emergence, poor fruit set, delayed ripening, reduced colour formation, and lower sugar content, all of which lower fruit quality and yield.

For generations, flu, cough, wounds and many skin diseases were treated with local herbs. Headmen still believed herbs are better for Cows treatment including difficulties in giving birth. However, because of ecosystem alteration, traditional doctors traveled to faraway areas and deep in forests to get herbs which exposed some to wild animals, yet herbs were in abundance before environmental situation shifted. Communities around Mt Elgon still enjoyed the supplies, however not as in the past and it required a national park acceptance or

encroachment of the park. In line with Patterson& Coelho (2009) and Bakure et al., (2022) who noted that even though medicines derived from flora were basis ground for today's medical treatment, jungle alteration is affecting plant and animal species abundance and degradation and modification of habitat. Most of these species with medicinal substances were essentially sheltered in grasslands and forest ecosystems. Tan et al., (2023) in turkey also concluded that drought has severe harmful effects on medicinal plants and spices, which are essential for healthcare. According to Selmar et al., 2017, regions that heavily rely on traditional medicine are impacted hard since it jeopardizes global health and local economies.

Residents said that their herds don't get pasture from grassland because of the nature disturbances. As shown above, both commercial and non-commercial livestock were practiced in the areas. Pastoralists were obliged to look for pastures (for cattle, goats, sheep) even when it required to enter deep into the forests. This is because livestock plays a key role in the food chain and source of livelihood. herdsmen from Bulambuli suffered more from the effects of forest degradation than those of Sironko district. Some respondents resolved to hybrid cows because of lack of pastures yet others considered moving to other districts where competition is less. In line with Godde et al., (2021) though the latter focused on how livestock production and food supply chain was exposed to natural shift.

Regulating services like Ability to reduce floods and drought is very essential, and it acts as a shield against disasters. This service also makes possible other services like provisioning and culture services. Because of forest degradation

which is a shield, followed by climate change, floods and droughts in Sironko catchment became so impactful. Many areas in both districts were seen so dried during dry season and when it rained, floods occurred. In some areas landslides were recorded because of floods. The capability to cut the impact of extreme temperature alteration events was greatly impacted mostly in Bulambuli compared to Sironko hence affecting agricultural and social sector as well. According to Bakure et al.'s (2022) analysis of the impact of warmer temperatures on ecological goods. Berhanu pointed out that climate change had an impact on regulating services including storing carbon, flood management, and environmental oversight. FAO (2018) also confirms that forest degradations opened doors to floods and soil erosions.

With deep sorrow, respondents acknowledged how the effects of interfering with the environment have made them change location and make them lose their ancestral homes and heritages. Some said that they had to travel long distances to connect with their ancestors in terms of worship. They were more attached to the area of residence, and they believed to have betrayed their forefathers. The danger of exposure explained why the government relocated forcefully some needihoods. Tengberg et al., (2012). Indicated that cultural heritage is inseparably coupled with community.

Human interference with nature has made generational farmers switch to fishing in wetlands for survival**;** others from farming to charcoal and wood production**;** from cowboys to businesspeople; and traditional doctors to beggars. Ecosystem degradation has influenced cultural and spiritual values loss. For example, some

tree species provide shelter during ancestral worship therefore considered holy too.

Reyers et al., (2013) confirmed that scenic beauty was affected by tree removal that came about due to LULC change. Studies by Bakure et al. (2022) and Tengberg et al. (2012) recognized the role that ethical and moral principles can have in supporting preserving biodiversity. He added that jungles degradation has threatened these services.

More ecological based mitigation measures should be implemented to reduce the impacts of current situation while preventing future risks. This includes more environmental awareness, restoration and protection of forest ecosystems

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Several conclusions are drawn based on the field findings in this study.

Forest ecosystems in Bulambuli and Sironko went through various degradation caused by land use change. In all the studied periods, built-up areas, farmland, forests, and tree plantations significantly increased at the expense of bushland, grassland, wetlands, and woodlands coverage. Area covered by bushlands, grassland, wetlands, and woodlands were the most altered. Land use types (built-up areas, farmland, and tree plantations) are high on the increase compared to land cover types in both Sironko and Bulambuli districts.

Several drivers of forest ecosystem services were established and rapid population growth, agriculture intensification, low employment opportunities, firewood and wood exploitation, expansion of land for settlement were noted to be the major drivers. Poor governance and management of ecosystems, climate change impacts and Poverty, Lack of alternative livelihoods and Illiteracy were among the growing drivers.

The supplies affected by forests ecosystem degradation were from provisioning services, regulating and cultural services. The most supplies affected by forest degradation included soil fertility and Source of food; ability to reduce floods and droughts; Spiritual sites and Sense of belonging. As results of forest degradation, people, agriculture sector and floral were very vulnerable to natural disasters like draught and floods.

Appropriate adaptation and mitigation strategies can reduce the effects of forest degradation climate change. This can be done through environmental education, enforcement of environmental acts, providing alternative sources of livelihood to reduce forest tress.

6.2 Recommendations

Based on the findings in this study, several recommendations are made to address the outstanding issues.

1. The expansion of crops and the increase in population were the primary causes of this shift in land utilization. If forest ecosystems are to be achieved sustainably, lawmakers should assess the current demographic policies and implement strict rules to prevent population increase.
2. Support formation of policies and bylaws. Increase support to the legal formation processes at all levels of local administration to ensure timely enactment and implementation if degradation activities are to be halted.
3. Increase diversification of livelihood options. Communities should be empowered to diversify livelihoods to reduce pressure on natural resources. Options that should be promoted include among others tree planting, diary support, bee keeping, allocation of infrastructure etc.
4. Strengthen capacity building initiatives of communities on climate adaptation measures. The content that should be included in the training modules are for example gender mainstreaming of adaptation interventions, environmental awareness, construction of energy saving cooking stoves, training in agroforestry, and availability of multiple use tree species.

5. More research should focus on mapping forest ecosystem services degradation and the effects on local people's culture. In river Sironko, many indignance people lost their culture and livelihood because of forest degradation. Forest example, medical herbs were hard to get yet it used to be the medicine for treating almost all diseases for generations.
6. Farther research should look at effects of forest degradation on crop production since forest degradation affected a lot of farmers in river Sironko.

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APPENDICES

Appendix I: Questionnaires /interview guide

Introduction

I am Ngarukiye Mukwiza Steven, a student of Kyambogo University pursuing master's degree of science in conservation and natural management.

I am carrying out research on the effect of forest degradation on ecosystem services in River Sironko Catchment. Therefore, as the primary stakeholders in this project you have been invited to actively participate in these assessments by volunteering information relating to status of Sironko and Bulambuli in relation to forest ecosystem services and climate change.

SECTION A: IDENTIFICATION VARIABLES

B. Research Assistants and Guide Identifiers

1. Name of Enumerator	
2.Telephone number	
3.Date of interview	
6.Name of Respondent	
7.Telephone number of Respondent	

C. Location Identifiers

a) District	1. Sironko	2. Bulambuli
b) Sub-county/Town council		
c) Parish/Ward		
d) Village/Cell		
f) GPS Coordinates	Eastings	Northings

SECTION B: RESPONDENT/HOUSEHOLD PROFILE AND CHARACTERISTICS

Q1	How are you related to the head of this household?	1. Household head 2. Spouse 3. Biological child 4. Stepchild 5. In-law 6. Grand child 7. Paternal/Maternal Parent

		8. Others
Q2	Sex of respondent	1. Male 2. Female
Q3	How old are you (Age in complete years)?	
Q4	What is your marital status?	1. Single/Never married 2. Legally Married 3. Cohabiting 4. Separated/Divorced 5. Widowed
Q5	What is your highest level of education attained?	1. No formal education 2. Primary level complete 3. Ordinary level incomplete 4. Ordinary level complete 5. Advanced level incomplete 6. Advanced level complete 7. Diploma 8. University degree 9. Post-graduate 10. Specialized/Vocational training 11. Other (Specify)…….
Q6	How many years have you lived in this village/location	_____ (figure)?
Q7	If household member is a PwD in the above question, what form of disability is the person(s) living with?	1. Physical disability 2. Speech/Oral disability 3. Hearing/Auditory disability 4. Sight disability 5. Mental disability 6. Other specify……

SECTION C: HOUSEHOLD ECONOMY

Q8	What are the various economic activities that the head of the household is engaged in? **(Multiple responses allowed)**	**Economic Activities**	**Monthly Income**
		1. Crop farming (subsistence less than 10 acres cultivated)	
		2. Crop farming commercial (above 10 acres)	
		3. Livestock farming Subsistence (<20 cattle)	
		4. Livestock commercial (more than 10 heads of cattle)	

		5. Self-employment	
		6. Wage-based activities/causal labouring	
		7. Salary	
		8. Personal Services	
		9. Rental, interest, dividend income land/property income)	
		10. Public transfer/pension	
		11. Private remittance/transfer	
		12. Charity/alms	
		13. Other (specify)	
Q9	Do you have access to land (own or opportunity to use)? Whether personal or borrowed	1. Yes 2. No	
Q10	If yes, please tell me the;	a) Number of acres_____ b) Acres under productive use_____	
Q11	For the land under productive use, what activities do you carry out on that land? **(Multiple responses allowed)**	1. Crop farming 2. Small-scale industry 3. Animal rearing 4. Conservation (Forest) 5. Poultry 6. Industrial complex 7. Fishing farming 8. Commercial building 9. Renting out land 10. Recreation facilities 11. Planted Forest 12. Cemetery (graves) 13. Nature-based hunting and gathering 14. Land under fallow 15. Earth-based extraction (clay, sand) 16. Houses/accommodation 17. Apiary (Bee keeping) 18. Other	
Q12	If land is under crop production, what crops are grown? **(Multiple responses allowed)**	1. Coffee 2. Tobacco 3. Cassava 4. Millet 5. Vanilla	

		6. Sunflower 7. Maize 8. Ground nuts 9. Cotton 10. Sim-sim 11. Rice 12. Peas 13. Tea 14. Banana 15. Sorghum 16. Beans 17. Sugar cane 18. Sweet potato 19. Irish Potato 20. Fruit trees 21. Plantain (Gonjja) 22. Vegetables 23. Others (specify)
Q13	If yes, which improved farming methods are adopted? **(Multiple responses allowed)**	1. Intensive tillage 2. Monoculture – one crop in the field 3. Intercropping 4. Crop rotation 5. Use of disease resistant seeds 6. Use of synthetic chemical fertiliser 7. Use of compost or other organic material (crop 8. residual/green manure) 9. Mulching 10. Irrigation of crops during dry season 11. Use of hybrid seeds to control pest and disease 12. management through 13. Use of disease-free seeds/seedlings to control 14. Application of chemical pest control (biopesticide/synthetic pesticide) 15. Improved harvesting and post-harvest techniques 16. Proper storage 17. Control livestock disease 18. Grafting 19. Other (Specify)

SECTION D: HOUSEHOLD, CURRENT VULNERABILITIES CAUSED BY CLIMATE CHANGE IMPACTS

Q15	If yes, what changes have you experienced resulting from climate changes that have you observed? **(Multiple responses allowed)**	**Year 2023**
	1. Increase in temperature	
	2. Reduction in temperature	
	3. Increase in the amount of rainfall/too heavy	
	4. Reduction in the amount of rainfall	
	5. Unpredicted rainfall patterns	
	6. More humid	
	7. Drought	
	8. Floods	
	9. Change in seasonality	
	10. Strong winds/storms	
	11. Increase in intensity of extreme events	
	12. Increase in spatial extent of extreme events.	
Q 16	Using a scale of 1-4 (1=Low, 2 = Moderate, 3 = High, 4 = Very High) rank the intensity/magnitude of the changes in climate changes for the following periods.	**Year 2023**
	1. Increase in temperature	
	2. Reduction in temperature	
	3. Increase in the amount of rainfall/too heavy	
	4. Reduction in the amount of rainfall	
	5. Unpredicted rainfall patterns	
	6. More humid	
	7. Drought	
	8. Floods	
	9. Change in seasonality	
	10. Strong winds/storms	
	11. Increase in intensity of extreme events	
	12. Increase in spatial extent of extreme events.	
Q 17	Have you observed any ecological changes because of the above-mentioned changes in **Q 15**?	1. Yes 2. No
Q 18	If yes, what ecological changes have you observed? **(Multiple responses allowed)**	**Year 2023**
	1. Reduction population abundance of certain animal species	
	2. Increase in population abundance certain animal species	
	3. Changes in body size of certain animals.	

	4. Changes in the timing of lifecycle events of some plants (such as flourishing).	
	5. Some plant species have become extinct	
	6. Changes in the distribution some of the plant population and species abundance.	
	7. Decline in habitat for wildlife	
	8. Decline in the size of wetlands	
	9. Decline in the size of forests	
	10. Change in crops grown by households	
	11. Reduction in size of some fish species from the wetlands and rivers	
	12. Soil erosion	
	13. Decline in soil fertility	
Q 19	Please, using a scale of 1-4 (1= Not affected, 2 = Low, 3 = Medium, and 4 = High) Rank the impact of climate change on ecological changes observed for the following periods?	**Year 2023**
	1. Reduction population abundance of certain animal species	
	2. Increase in population abundance certain animal species	
	3. Changes in body size of certain animals.	
	4. Changes in the timing of lifecycle events of some plants (such as flourishing).	
	5. Some plant species have become extinct	
	6. Changes in the distribution some of the plant population and species abundance.	
	7. Decline in habitat for wildlife	
	8. Decline in the size of wetlands	
	9. Decline in the size of forests	
	10. Change in crops grown by households	
	11. Reduction in size of some fish species from the wetlands and rivers	
	12. Soil erosion	
	13. Decline in soil fertility	

SECTION E: MAJOR DRIVERS OF FOREST DEGRADATION AND ECOSYSTEMS SYSTEM OF RIVER SIRONKO

Q 20	Are you aware of any major drivers of vulnerability of forests ecosystems of River Sironko to climate change?	1.yes 2.No
Q 21	If yes, what are the major drivers of forests degradation and ecosystems services in River Sironko? **(Multiple responses allowed)**	**Year 2023**
	1. Low employment opportunities	
	2. Climate change impacts (floods, drought)	
	3. Poor governance and management of ecosystems	
	4. Rapid population growth	
	5. Poverty	
	6. Lack of alternative livelihoods	
	7. Cultural attitudes	
	8. Change in consumption patterns of wetland resources	
	9. Change in consumption patterns of forest resources	
	10. Illiteracy	
	11. Community alienation/marginalization	
	12. Expansion of agricultural land	
	13. Expansion of land for settlement	
	14. Natural resources extraction	
	15. Land use changes	
	16. Changes in agricultural production patterns	
	17. Infrastructure development projects	
	18. Emergency of invasive species	
Q 22	What are the major ecosystems vulnerabilities in this community? **(Multiple responses allowed)**	**Year 2023**
	1. Decline in harvestable resources	
	2. Deterioration of water quantity/quality	
	3. Drying of rivers	
	4. Extinction of species	
	5. Habitat fragmentation	

	6. Loss of aesthetic value	
	7. Loss of biodiversity	
	8. Loss of habitats	
	9. Loss of system productivity	

SECTION F: MAJOR ECOSYSTEMS SERVICES OF R. SIRONKO

Q 23	Are there forests in this village/subcounty	
Q 24	If yes, please provide the local name	
Q25	Please which of the following services and goods does your household get from the forests near to you. **(Multiple responses allowed)**	**Year 2023**
	1. Source of food (e.g., fruits, nuts, mushrooms, honey, or spices)	
	2. Source of fuelwood,	
	3. Source of fibre,	
	4. Source of medicinal plants	
	5. Source of building materials	
	6. Raw materials for industrial products	
	7. Source of pastures (for cattle, goats, and sheep etc)	
	8. Climate regulation (formation of rains)	
	9. Reduces the impact of extreme climate change events (e.g. by slowing down water runoff/floods, breaking strong winds etc)	
	10. Reduce the spread of pollutants from the atmosphere	
	11. Absorbers of greenhouse gasses	
	12. Important in the formation of soils,	
	13. Important in keeping the soils together through reducing soil erosion.	
	14. Forests help soils retain and deliver nutrients which support crop and livestock production	
	15. They purify the water in the river through filtration	
	16. Sources of pollinators (e.g. insects for vegetables, legumes, and fruits)	
	17. Act as natural pest controllers	
	18. Offer aesthetic beauty (Hunting, bird viewing etc)	
	19. Cultural importance (worship places)	
Q 26	Have experienced any declines in the benefits you were getting from forests of this area?	1. Yes 2. No

Q 27	If yes, ecosystem services are declining, what is the cause of decline? **(Multiple responses allowed)**	
	1. Over exploitation of wetlands resources	
	2. Reclamation of wetlands	
	3. Rapid population growth	
	4. Agricultural intensification	
	5. Expansion of land for settlement	
	6. Competition for good arable land	
	7. Excessive natural resources extraction	
	8. Intensification of infrastructure development projects	
	9. Increase in invasive species	
	10. Decline in harvestable resources	
	11. Deterioration of water quantity/quality	
	12. Drying of rivers	
	13. Extinction of species	
	14. Habitat fragmentation	
	15. Loss of aesthetic value	
	16. Loss of biodiversity	
	17. Loss of habitats	
	18. Loss of system productivity	
Q 28	Please, using a scale of 1-4 (1= Not impact, 2 = Low, 3 = Medium, and 4 = High) Rank the impact of the following factors on the availability of ecosystem services?	**Year 2023**
	1. Over exploitation of wetlands resources	
	2. Rapid population growth	
	3. Agricultural intensification	
	4. Expansion of land for settlement	
	5. Competition for good arable land	
	6. Excessive natural resources extraction	
	7. Intensification of infrastructure development projects	
	8. Increase in invasive species	
	9. Decline in harvestable resources	
	10. Deterioration of water quantity/quality	
	11. Drying of rivers	
	12. Extinction of species	
	13. Habitat fragmentation	
	14. Loss of aesthetic value	
	15. Loss of biodiversity	
	16. Loss of habitats	

	17. Loss of system productivity	
Q 29	Please what are the impacts of forest ecosystem degradation? **(Multiple responses allowed)**	**Year 2023**
	1. Biodiversity loss leading to extinction of some species	
	2. Loss of Ecosystems integrity	
	3. Decline in harvestable resources	
	4. Decreased revenue	
	5. Increased conflicts	
	6. Increased poverty	
	7. Food insecurity	
	8. Scarcity of water for domestic use	
	9. Scarcity of water for production	
	10. Reduced biomass/firewood	
	11. Reduction in the quality of water	
	12. Reduction in soil productivity	
	13. Reduction in crop yields	
	14. Reduction in the quality of livestock products	
	15. Increase in the regeneration of invasive species	
	16. Increased conflict between wildlife and humans	
	17. Conflict for scarce resources due to growing demand	
	18. Increase in number of endangered species	
	19. Increase in desert like conditions	
	20. Increase susceptibility to droughts	
	21. Increased susceptibility to floods	
	22. Increased rainfall variability	
	23. Unemployment	
	24. Increase in household expenditure	
	25. Increase in both human diseases	
	26. Increase in livestock diseases	
	27. Increase in human rights abuses	
Q 30	Please, using a scale of 1-4 (1= Not impact, 2 = Low, 3 = Medium, and 4 = High) Rank the following impacts of ecosystem degradation?	**Year 2023**
	1. Biodiversity loss leading to extinction of some species	
	2. Loss of Ecosystems integrity	
	3. Decline in harvestable resources	
	4. Decreased revenue	
	5. Increased conflicts	
	6. Increased poverty	

	7. Food insecurity	
	8. Scarcity of water for domestic use	
	9. Scarcity of water for production	
	10. Reduced biomass/fuel	
	11. Reduction in the quality of water	
	12. Reduction in soil productivity	
	13. Reduction in crop yields	
	14. Reduction in the quality of livestock products	
	15. Increase in the regeneration of invasive species	
	16. Increased conflict between wildlife and humans	
	17. Conflict for scarce resources due to growing demand	
	18. Increase in number of endangered species	
	19. Increase in desert like conditions	
	20. Increase susceptibility to droughts	
	21. Increased susceptibility to floods	
	22. Increased rainfall variability	
	23. Increased susceptibility to landslides	
	24. Unemployment	
	25. Increase in household expenditure	
	26. Increase in both human diseases	
	27. Increase in livestock diseases	
	28. Increase in human rights abuses	

MEASURES EMPLOYED TO PREVENT, PREPARE; MITIGATE; RESPOND; AND RECOVER CURRENT AND OR FUTURE CLIMATE CHANGE VULNERABILITIES

Q 31	Do you put any measures to prevent/prepare for impacts of climate change?	**1.yes** **2.No**
Q 32	If yes, what measures do you put in to prevent/prepare for climate change? **(Multiple responses allowed)**	**Year 2023**
	1. Store food during bumper harvest	
	2. Construction of flood control platforms	
	3. Construction of houses on safe elevated areas	
	4. Wetland restoration and management	
	5. Forest restoration and management	
	6. Rainwater harvesting	
	7. Saving for future uncertainties	
	8. Insuring against climate change effects	

	9. Seek climate information to plan against future risks	
	10. Livelihoods diversification	
	11. Crop diversification to include moisture resistant species, cover cropping	
	12. Dig trenches, planting pits, vegetation strips, ridge tillage to trap water and retain water in gardens	
	13. Digging terraces to prevent landslides and soil erosion	
	14. Mulching gardens to retain moisture in the soils	
	15. Plant drought-resistant crops	
	16. Plant fast maturing crop varieties	
	17. Plant trees to regulate climate	
	18. Practice agro forestry	
	19. Zero/minimal tillage farming system	
	20. Vaccinating of livestock	
	21. Migration to other areas	
	22. Fallowing	
	23. Others	
Q 33	Do you put in place any measures to mitigate against impacts of climate change?	**1.yes** **2. No**
Q 34	If yes, what measures do you put in to mitigate against climate change? **(Multiple responses allowed)**	**Year 2023**
	1. Store food during bumper harvest	
	2. Construction of flood control platforms	
	3. Construction of houses on safe elevated areas	
	4. Wetland restoration and management	
	5. Forest restoration and management	
	6. Rainwater harvesting	
	7. Saving for future uncertainties	
	8. Insuring against climate change effects	
	9. Seek climate information to plan against future risks	
	10. Livelihoods diversification	
	11. Crop diversification to include moisture resistant species, cover cropping	

	12. Dig trenches, planting pits, vegetation strips, ridge tillage to trap water and retain water in gardens	
	13. Digging terraces to prevent landslides and soil erosion	
	14. Mulching gardens to retain moisture in the soils	
	15. Plant drought-resistant crops	
	16. Plant fast maturing crop varieties	
	17. Plant trees to regulate climate	
	18. Practice agro forestry	
	19. Zero/minimal tillage farming system	
	20. Migration to other areas	
	21. Others	

Thank You