

**LAND USE LAND COVER CHANGE AND PERCEPTION OF DRIVERS IN THE
BANGWEULU WETLAND AND SURROUNDING AREAS, ZAMBIA**

By

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A thesis submitted to the University of Zambia in partial fulfilment of the
requirements for Master of Science degree in Integrated Water Resources Management

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CERTIFICATE OF APPROVAL

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ABSTRACT

Wetlands are essential for the natural function of ecosystems, because they regulate floods and have many other significant functions. However, land use-land cover (LULC) changes are the main drivers of wetland deterioration globally, and Zambia is no exception. This study examined LULC changes in the Bangweulu Wetland and surrounding areas using remote sensing and GIS techniques, while questionnaires and key informants were used to identify the drivers of the observed changes. The general objective of the study was to assess land use /land cover (LULC) changes in the Bangweulu Wetland and surrounding areas. To realize this, land use was reclassified into five categories, namely, settlements, grassland, cropland, water and forest.

The findings revealed a decrease in forest coverage from 45,298.93 km² in 1990 to 33,233.52 km² in 2020. Similarly, the area of grasslands decreased from 32,557.91 km² in 1990 to 26,418.19 km² in 2020, while the area of water decreased from 2410.72 km² in 1990 to 2278.31 km² in 2020. Conversely, settlement land expanded from 356.69 km² in 1990 to 2,210.38 km² in 2020, while cropland increased from 165.27 km² in 1990 to 5,108.13 km² in 2020. The study also revealed several significant drivers of LULC change in the Bangweulu Wetland and surrounding areas.

Population growth scored highest, with a mean of 3.76 out of 5, followed by the expansion of human settlements (3.66 out of 5), the decline of ecosystem services (3.57 out of 5) and the decline of forests (2.64 out of 5). In comparison, minor drivers such as the built environment (2.21 out of 5), recreation (1.54 out of 5) and industry (1.34 out of 5) exerted less influence on land use changes.

The factors influencing the perceived causes of LULC included agricultural development and energy-related factors, driven by an increase in market demand for charcoal and cash crops leading to heightened agricultural activities and the conversion of forest cover. Understanding these drivers and local perceptions is crucial for informing effective land management strategies and promoting sustainable development. This knowledge can guide policies and interventions aimed at addressing the underlying causes of LULC changes and conserving the vital ecological functions of the Bangweulu Wetland.

DEDICATION

To my lovely parents who have always inspired me to pursue my goals.

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ACRONYMS AND ABBREVIATIONS

CBD	Convention on Biological Diversity
CSO	Central Statistics Office
ESV	Ecosystem Service Values
FAO	Food and Agriculture Organization
FD	Forestry Department
GPS	Global Positioning System
GRZ	Government of the Republic of Zambia
IAS	Invasive Alien Species
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management
LC	Land Cover
LUC	Land Use Change
LULC	Land Use/Land Cover
MLC	Maximum Likelihood Classification
NASA	National Aeronautics and Space Administration
UNEP	United Nations Environmental Programme
USGS	United States Geological Survey
SPSS	Statistical Package for the Social Sciences
WWF	World Wildlife Fund
WARMA	Water Resources Management Authority
ZMD	Zambia Meteorological Department

CHAPTER 1: INTRODUCTION

1.1 Background

The Convention on Biological Diversity (CBD) states that wetlands are essential to humanity's future (Secretariat of the Convention on Biological Diversity, 2015). This is because wetlands may be conserved and used sustainably to address a number of future concerns, including food and water security, human health, hazard risk reduction and climate change resistance (FWA-SCARED, 2011; Secretariat of the Convention on Biological Diversity, 2015).

Wetlands are significant natural ecosystems and landscapes that support plant and animal life as well as wetland agriculture and other water-related activities (Courouble et al., 2021). They are known to control flooding, groundwater recharge, flow regimes and water quality (Liu et al., 2004). Wetlands are defined as areas of land that are in close proximity to bodies of water, whether permanent or temporary, still or moving, fresh or brackish, or even parts of the marine environment (Ramsar Convention Secretariat, 2007).

The Ramsar Convention aims to encourage the smart use of wetlands for the sake of the environment as well as the sustainability of the livelihoods of those who are reliant on them (Ramsar Convention Secretariat, 2007). This is because the main causes of the deterioration of freshwater, biodiversity and the effects on the flooding regimes of wetlands are global climate change and land use change (Nachtergaele et al., 2016).

Land use change has an impact on the basic resources of land, including soil; it is defined as any way in which humans alter the natural landscape from one specific use to another (Maitima et al., 2010). With factors such as population growth being a major contributor to current land use change in wetlands (Phethi and Gumbo, 2019), accurate assessments of land use changes over time are required for the evaluation of wetland ecosystem dynamics and the development of comprehensive management policies and land use planning (Jamal and Ahmad, 2020).

1.2 Statement of the Problem

Despite the significant roles of wetlands, it is estimated that more than 81% of the world's wetlands have disappeared since the 1900s (Ramsar Convention on Wetlands, 2018), which implies a decrease in the freshwater supply to billions of people worldwide as well as a 76% decrease in biodiversity between 1970 and 2010 (Ramsar Convention Secretariat, 2010;

Secretariat of the Convention on Biological Diversity, 2015). The loss is significantly worse in Asia. This means that 1 to 2 billion people are losing access to fresh water globally. Moreover, traditional wetland livelihoods, flood control and carbon storage are all negatively impacted (Wetlands International Secretariat, 2014).

According to the Convention on Wetlands (2022), the loss of wetlands is associated with human activities in and near wetland areas, because significant changes in land use, particularly increases in agriculture and grazing, urban infrastructure development, air and water pollution (Secretariat of the Convention on Wetlands, 2022) and water diversion, are primary causes of wetland degradation worldwide (McLellan et al., 2014). The World Wild Fund's (WWF's) Living Planet Index also indicates that populations of freshwater species continue to decrease; hence, this has an impact on biodiversity (Alam et al., 2011).

The general health of wetlands around the world continues to suffer from a variety of detrimental effects as a result of agricultural regions, increased residential and commercial land utilization (Alam et al., 2011). Because the Bangweulu Wetland was officially identified as a wetland of international significance (Secretariat, 2002), it was chosen as a site study because there is little to no information on the effects of human activity in the wetland, the extent of wetland changes and its effects on ecosystem services.

It is crucial to understand specific human activities, quantify wetland loss and degradation, and assess ecosystem services, particularly freshwater availability and biodiversity. Addressing these knowledge gaps can help develop targeted conservation strategies for the Bangweulu Wetland and its surrounding areas.

1.3 Objectives of the Study

The general objective of the study was to assess land use /land cover (LULC) changes in the Bangweulu Wetland and surrounding areas. This analysis was performed to assess the extent and patterns of LULC changes in the Bangweulu Wetland and its surroundings over a specific period (1990–2020).

The specific objectives of the study were to:

- i. Assess land use /land cover change between 1990 and 2020 using Landsat satellite images;
- ii. identify the perceived drivers of observed changes in the wetland; and

- iii. determine the factors that influence the perceived causes of LULC change in the Bangweulu Wetland and surrounding areas.

1.4 Research Questions

The study answered the following research questions:

- i. What land use land cover changes have taken place between 1990 and 2020 in the Bangweulu wetlands and its surrounding areas?
- ii. What are the perceived drivers of the observed land use changes from the local communities? and
- iii. What factors influence the perceived drivers of change in the Bangweulu Wetland and surrounding areas?

1.5 Significance of the Study

The research conducted has significantly contributed to enhancing our comprehension of the dynamics of land use and land cover changes within the Bangweulu Wetland and its surrounding areas. Furthermore, it serves as a foundational reference point for subsequent studies in the area. The insights derived from this study offer a valuable tool for gauging the present conditions of the Bangweulu Wetland and the overall viability of the land use practices employed within its vicinity.

Given the profound ecological dependence of wetlands, the findings of this study are relevant because they offer a means to assess the ecological health of the Bangweulu Wetland and its surroundings. By utilizing these findings, it becomes possible to evaluate the degree of safety and sustainability associated with existing land use practices. Considering the delicate balance that wetlands strike with their ecological framework, this study has also proposed recommendations aimed at fostering the adoption of more sustainable approaches for conducting various activities in the area.

CHAPTER 2: LITERATURE REVIEW

This chapter presents a review of the literature regarding land use /land cover changes and their drivers both globally and in Zambia.

2.1 Importance and Challenges of wetlands

Wetlands occupy a crucial position within landscapes, providing assorted advantages to both human populations and the varied ecosystems they support (Lahasing et al., 2015). They stand as indispensable custodians of the Earth's elaborate climatic equilibrium, acting as protectors of the immense diversity that graces our ecosystems (Acreman and Bullock, 2003).

Their significance encompasses a wide spectrum of benefits, including safeguarding and enhancing water quality, while also serving as essential habitats for aquatic and wildlife species (Ward et al., 2022). This role they play also extends its embrace to encompass the safeguarding of human well-being in an interconnected web of ecological intricacy (Hu et al., 2017). These distinct attributes of wetlands enable them to perform vital roles, such as mitigating floods and maintaining the flow of surface water, especially during periods of drought (Bae et al., 2017). However, wetland ecosystems are persistently challenged by a number of pressing issues that span geographical boundaries (Ghajarnia et al., 2020). The degradation or loss of wetlands has significant and profound consequences. These include heightened risks of flooding, potential species extinction and compromised water quality (Sarron, 2005). These negative outcomes underscore the fundamental importance of wetlands in maintaining ecological equilibrium and the health of local and global environments (Odote, 2019). Unfortunately, during recent decades, the conversion of wetlands into agricultural landscapes, shifting land use changes, deforestation, climate change, the relentless harvesting of natural resources and the infiltration of alien species have all converged to pose threats to both wetland species and vital services (Zorrilla-miras et al., 2014).

As we stand at the crossroads of maintaining these irreplaceable ecosystems, it is important to recognize the interdependence that binds wetlands with the fate of our planet (Gantioler et al., 2009). Nonetheless, there is a viable path to avoid these severe outcomes: by recognizing the value of conserving and even restoring compromised or lost wetlands (Alikhani et al., 2021). Through collaborative efforts in preservation and restoration, the invaluable roles that wetlands naturally fulfil can be preserved, ensuring ecosystem stability and the sustainable provision of their benefits (Michel, 2016).

2.2 Global Studies on the Effects of LULC Changes on Wetlands

Throughout history, people have altered the land to obtain the things they needed to survive, but at a slower rate than it is now (Ellis, 2021). At the local, regional and global levels, the recent high rate of exploitation has resulted in previously unheard-of alterations in ecosystems and environmental processes (Parveen et al., 2018).

In their study on the impacts of land management and land-cover change, Luysaert et al. (2014) reported that approximately three-quarters of the Earth's land surface has been altered by humans within the last millennium. Similarly, Winkler et al., (2021) stated that successfully tackling global sustainability challenges such as climate change, biodiversity loss and food security depends on land use change, since it strongly affects carbon sources and sinks, which causes habitat loss and underpins food production (Winkler et al., 2021).

Other reviewed studies, such as (Liu et al., 2004; Msoffe et al., 2011; Mosnier et al., 2016; Islam et al., 2018; and Jamal and Ahmad, 2020), have indicated that there is still an increase in land use changes, while Hu and others have provided more insights into the shifts and alterations occurring in crucial environmental procedures that indicate that a planet is heavily influenced by human activities. They also delve into the secondary impacts of climate change on the land surface, particularly in northern ecosystems (Hu et al., 2021). Additionally, Munthali et al., (2019) reported a notable decrease in forested areas, farmland, wetlands and water bodies, while urban development and unproductive land exhibited substantial growth throughout the analysed timeframe. Factors such as gathering firewood, producing charcoal, population expansion and economic hardship were identified by local communities as significant influences behind the shifts in land use and land cover (LULC) within the examined region (Munthali et al., 2019).

Alterations in land utilization continue to play a significant role in the reduction of ecosystem benefits. As highlighted in Zorrilla's study, approximately 70.5% of original natural or seminatural land covers have been transformed into intensive agricultural and other single-purpose applications. This shift has hindered the capacity of ecosystems to carry out regulatory functions. Simultaneously, 31% of wetland areas have been subjected to severe preservation measures, impacting the cultural and provisioning benefits they provide (Zorrillamiras et al., 2014). According to research by Assefa, Eneyew and Wondie, there has been a serious reduction in wetlands and water bodies in Bahir Dar city over the past 35 years (1984-2019), primarily as a result of the growth of built-up areas and cultivated land. The findings

also revealed a significant decline in ecosystem service values (ESVs) in the urban and peri-urban districts of Bahir Dar city (Assefa et al., 2021).

Cai and other researchers also revealed that by using more water resources than necessary, humans are deciding the fate of wetlands, which could lead to future problems. They examined how changing land cover affects the water environment of wetland ecosystems and their research revealed that wetland ecology is affected in a specific way by changes in land cover (Cai et al., 2022). This study further revealed that climate change and rapid agricultural growth have reduced the global area of wetlands in recent years. Hence, changes in land use and their spatial consequences for wetland ecosystems are major concerns for geographical experts and environmentalists (Cai et al., 2022). Moreover, although wetlands are known to be critical to the delivery of ecosystem services, they are among the ecosystems experiencing the greatest transformations globally (Kamble et al., 2012). Land use disrupts the surface water balance and the partitioning of precipitation into evapotranspiration, runoff and groundwater flow. Surface runoff and river discharge generally increase when natural vegetation (especially forests) is removed (Foley et al., 2005). In Spain, land-use change for intensive agriculture and urbanization is a major driver of biodiversity loss, with 60% of the original wetland area converted over the last five decades. According to the Spanish sub global ecosystem assessment, 62% of the ecosystem services provided by wetlands have declined over the last fifty years (Zorrilla-miras et al., 2014).

The inaugural Global Wetlands Outlook, published in 2018 by Gardner and Finlayson, presented an assessment of the state of the world's wetlands. This comprehensive report revealed that despite their vast extent, covering approximately 1.2 billion hectares, which is even larger than the land area of Canada, wetlands are facing a rapid and alarming decline (Ramsar Convention on Wetlands, 2018). One of the most concerning findings of the report was the significant loss of natural wetlands, with a staggering 35% reduction in their extent since 1970 (Davidson, 2014). This decline was attributed to a multitude of stressors and human activities, including drainage, pollution, invasive species, unsustainable exploitation, disruption of natural flow patterns and the overarching influence of climate change (Ramsar Convention on Wetlands, 2018). Perhaps the most alarming revelation in the report was that wetlands disappeared at a rate three times faster than that of forests (Davidson, 2014). The primary driver of this catastrophic loss was identified as land-use change, with agriculture emerging as the single most substantial contributor to wetland degradation (Rueda

and Lambin, 2014). In fact, more than half of the world's most endangered wetlands are adversely affected by agricultural activities, according to Gardner and Finlayson's assessment (2018). Furthermore, the report highlighted an accelerating trend in wetland loss due to the compounding effects of climate change. Factors such as rising sea levels and altered hydrology caused wetlands to disappear at an even faster rate than previously anticipated, intensifying the global crisis facing these vital ecosystems (Gardner and Finlayson, 2018). The 2018 Global Wetlands Outlook served as a wake-up call, revealing the critical need for immediate and concerted efforts to protect and restore wetlands worldwide. The rapid loss of wetlands, their degradation and the increasing influence of climate change on their decline underscore the urgency of conserving these invaluable ecosystems for both ecological stability and human well-being (Jenny et al., 2020). These findings underscore the importance of addressing the various drivers of wetland loss and implementing sustainable management practices to safeguard these vital ecosystems for future generations (Jenny et al., 2020).

2.3 Zambian Studies on The Effects of LULC Changes on Wetlands

Wetlands, a vital component of Zambia's diverse landscape, encompass a significant portion of the country's total area, constituting approximately 14 to 19% of the country (Ministry of Land and Natural Resources, 2018). These unique ecosystems exhibit varying hydrological characteristics, ranging from periodically wet and periodically dry to permanently flooded with water layers that do not typically exceed several meters. Within this classification, three prominent types of wetlands are recognized: permanent swamps, floodplains and dambos.

The importance of wetlands in Zambia has gained international recognition since the country's ratification of the Ramsar Convention in 1991. Notably, eight of these wetlands have been designated as wetlands of international importance, highlighting their global significance (WWF, 2018). These designated wetlands include the Kafue Flats Wetland, Bangweulu Swamps, Barotse (Zambezi) Floodplain, Luangwa Floodplain, Busanga Swamps, Lukanga Swamps, Lake Mweru-wa-Ntipa and Lake Tanganyika. Each of these wetlands harbours unique ecological characteristics, serving as critical habitats for numerous species and contributing to the preservation of biodiversity. As Zambia continues to navigate the complexities of wetland management, a balance between human utilization and ecological preservation has been encouraged by Handavu, Chirwa and Syampungani., (2019),

who conducted a study in Zambia's Copperbelt Miombo woodlands, exploring how socioeconomic factors influence changes in land- use and land- cover. Local communities were found to be heavily reliant on forest resources. Their study emphasized that any strategies to counter deforestation should effectively address the social and economic challenges faced by these communities to ensure the long-term health and vitality of these invaluable ecosystems (Handavu et al., 2019). In another study by Changwe (2020), the degradation of the Lukanga Wetland in Zambia was evaluated by analysing shifts in land use and land cover over two decades (1997-2017). This study revealed significant and notable alterations in the Lukanga Wetland during this time frame. The study attributed these changes to the growing need for land for farming and housing due to a rising population. The study also revealed that a considerable portion of the landscape was converted into agricultural fields and settlements, leading to a decline in forested areas and an expansion of grasslands over the two decades. This study highlighted the exponential growth of settlements and cultivated land, as well as the decrease in wetland coverage due to the expansion of agriculture and built environments (Changwe, 2020).

Research on land use and land cover changes in Zambia's Solwezi Copper Mining District (Takam et al., 2021) revealed significant transformations between 1995 and 2019. The study noted simultaneous declines in forested areas and water bodies, along with increases in agricultural, barren, built-up and mining areas. The researchers projected further reductions in forested areas due to the allure of mining, rapid population growth, increased settlements and the demand for agricultural land to meet local needs. Additionally, Banda et al., (2023) conducted a study demonstrating a 24.3% annual rate of land use change in the BFP, Zambia. They attributed this change to factors such as climate variations, infrastructure development, demographics, technological advancements and agricultural activities. Land use practices such as road construction, bridge conversion and clay soil mining were identified as contributors to this transformation, ultimately posing a threat to the current state of the wetland in the Barotse Flood Plain (Banda et al., 2023).

Studies in Zambia revealed the challenges that threaten the existence and valuable services that wetlands provide to both the environment and society. One of the primary threats to wetlands in Zambia is the spread of invasive alien species (IAS). A study conducted on invasive species systems in Zambia defined IASs as nonnative plants and animals that can rapidly colonize wetland ecosystems, outcompete native species and disrupt delicate ecological balances. As

these invasive species establish themselves, they can alter hydrological patterns, degrade habitat quality, and diminish biodiversity, ultimately undermining wetland functioning (Constantine et al., 2022). A similar study conducted by Musonda Mumba on the Kafue flats revealed that IAS, such as *Mimosa Pigra*, are spreading and need to be controlled (Mumba, 2002).

Another study by the Ministry of Land of Natural Resources showed that the encroachment of shrubs and the expansion of human settlements also pose significant challenges to wetland preservation because as human populations expand, wetlands often become targets for urban development, agriculture and infrastructure projects. This encroachment not only leads to the loss of wetland habitats but also disrupts natural water flow, altering hydrological dynamics and potentially exacerbating flooding risks in surrounding areas (Ministry of Land and Natural Resources, 2018). The challenges facing wetlands in Zambia are multifaceted and interconnected, stemming from human activities, environmental changes and inadequate management. Addressing these threats requires a concerted effort involving stakeholders from the government, civil society, and local communities. By implementing sustainable land use practices, enforcing effective regulations, and promoting awareness and education, Zambia can strive to protect and restore its invaluable wetland ecosystems for the benefit of present and future generations.

2.4 Land Use Change

The degradation of wetlands is accelerating due to a confluence of factors, including the increasing density of human settlements, unregulated industrial expansion, rapid urbanization, habitat destruction, the indiscriminate discharge of wastewater and heightened exposure to natural hazards. This unfortunate trend has led to a significant decline in the biodiversity of wetland ecosystems over time, as observed in the research conducted by Alikhani, Nummi and Ojala, (2021).

The transformation in land use patterns has brought about the establishment of towns and urban areas to accommodate the burgeoning population and has also brought about an increase in agricultural practices (Samuel and Atobatele, 2019). This development, while catering to human needs, has had unintended consequences, such as the indiscriminate use of pesticides, which has further worsened the problem (Ncheuveu et al., 2021). The resulting environmental degradation and broader impacts of climate change have also been implicated as potential drivers of decreasing trends in wetland biodiversity (Kapos et al., 2008). To effectively address

the pressing issue of dwindling wetland biodiversity, it is imperative for governments and relevant authorities to adopt robust and proactive measures. Among these measures, a key emphasis should be placed on formulating and enforcing strict land use policies that safeguard the delicate balance between human development and ecological integrity (Nachtergaele et al., 2016). Moreover, there is a crucial need to encourage the expansion of organic agriculture practices, which can curtail the harmful effects of pesticides and chemical runoff on wetland ecosystems (Sellamuttu et al., 2008). Mitigating the detrimental effects of industrial activities can also be essential in this conservation endeavour. The implementation of bioremediation techniques to treat industrial effluents before their release into wetlands can substantially mitigate their negative impact on biodiversity. Furthermore, the adoption of comprehensive and sustainable environmental laws can serve as a foundational framework for guiding human activities in and around wetlands, ensuring long-term ecological health (Chen et al., 1999).

The urgency of conserving wetland biodiversity demands a comprehensive and multifaceted approach. The convergence of urban development, industrial growth, environmental degradation and climate change necessitates strategic interventions such as informed policy making, ecologically friendly agricultural practices, advanced pollution management and a legal framework that prioritizes the preservation of these vital ecosystems (Gumbo, 2019).

2.5 Drivers of Land Use Changes in Wetlands

Land use change is a complex process influenced by a multitude of interconnected variables, each exerting its own influence and often interacting in intricate ways (Verburg et al., 2019). These factors collectively shape the way land is utilized and transformed over time, with implications for ecosystems, economies, societies and overall sustainability (Foley et al., 2005; Ellis, 2021). Understanding the interplay of these variables is essential for effective land use planning and management. These factors include biophysical, economic, technical, demographic and climate changes (Briassoulis, 2000).

Biophysical factors, encompassing the physical characteristics of the land, such as topography, soil quality and hydrology, play a fundamental role in determining suitable land uses (Foley et al., 2005). The availability of fertile soil, water resources and suitable terrain significantly influences decisions about agriculture, forestry and infrastructure development.

Economic considerations also weigh heavily on land use choices. Market demands, profitability and returns on investments guide decisions regarding whether to allocate land for agricultural production, industrial activities or urban development (Lambin and Meyfroidt, 2011). The economic viability of different land uses often shifts over time, influencing patterns of land conversion.

Technical factors, including advancements in agricultural practices, irrigation methods and land management techniques, can shape the feasibility and productivity of various land uses (Turner II, Lambin and Reenberg, 2007). Innovations in technology can increase agricultural yield, enhance resource efficiency and open up new possibilities for sustainable land use practices.

Demographic factors, driven by population growth and migration, exert significant pressure on land resources. Urbanization, for example, leads to the conversion of agricultural or natural areas into urban landscapes, altering land use patterns and often contributing to habitat fragmentation (Gutu Sakketa, 2023).

Climate change is a transformative variable that amplifies the complexities of land use change. Changes in temperature, precipitation patterns and extreme weather events directly impact land suitability for different activities (Intergovernmental Panel on Climate Change, 2019). For instance, prolonged droughts or increased rainfall can render certain areas less suitable for agriculture or settlement due to water scarcity or flooding risks.

The effects of climate change also extend to water management. The need for water storage and management becomes more critical in the face of altered precipitation patterns, with implications for agriculture, drinking water supply and ecosystem health (Intergovernmental Panel on Climate Change, 2019). Temperature and humidity variations impact agricultural productivity, potentially affecting crop yields and altering the distribution of suitable cultivation zones. In the context of wetlands, climate change poses an especially potent threat. Rising temperatures and altered precipitation patterns can disrupt the delicate balance of wetland ecosystems, affecting biodiversity, water quality and habitat availability (Ramsar Convention on Wetlands, 2021). The Ramsar Convention on Wetlands recognizes climate change as a key factor impacting wetland integrity and species survival.

The broader global megatrends mentioned above, such as population growth, globalization, consumerism and urbanization, are also intertwined with these factors (Artuso and Guijt, 2020). Increased consumption patterns and urban sprawl, driven by globalization and consumerism, contribute to changes in land use as the demand for resources and infrastructure escalates.

Land use change is a dynamic process shaped by a web of variables, including biophysical, economic, technical, demographic, climatic and broader societal factors (Foley et al., 2005; Turner II, Lambin and Reenberg, 2007). The intricate interactions between these variables underscore the complexity of managing and planning for sustainable land use in a changing world. As the effects of climate change and other global trends continue to unfold, a comprehensive understanding of these interconnections becomes even more critical for responsible land management and the preservation of ecosystems.

2.6 Climate Change

Climate change has become a major threat to sustainable development in Zambia. The country is already experiencing climate-induced hazards, which include drought and dry spells, seasonal and flash floods and extreme temperatures (Simatele, 2016). Some of these hazards, especially droughts and floods, have increased in frequency and intensity over the past few decades and have adversely impacted food and water security, water quality, energy and livelihoods, especially in rural communities (CIAT and World Bank, 2017). The overarching threat of climate change also looms large over wetlands in Zambia. Altered precipitation patterns, increased temperatures and extreme weather events can disrupt the delicate balance of wetland ecosystems. These changes can affect water availability, habitat suitability and the distribution of wetland-dependent species (Kalantary, 2010). The future trends in the country are towards a higher average temperature, a possible decrease in total rainfall and some indication of heavy rainfall events (Ministry of Tourism Environment and Natural Resources, 2010). An assessment of potential climate impacts shows that they will seriously undermine the efforts to improve the livelihoods of Zambians if left unaddressed. This assessment further analysed the negative impacts of climate change on key economic sectors, including water. In this way, climate change impacts may threaten the survival of wetlands (Ministry of Land and Natural Resources, 2018).

2.7 Consequences of Land Use Changes on the Earth's Terrain

Over countless millennia, human interactions with the Earth's terrain have had a transformative influence on its environmental dynamics. The complicated interplay of biodiversity, ecosystems, landscapes and climatic conditions across the globe has been significantly reshaped by the increasingly intensive manipulation of land by humans (Endfield, 2009). This manipulation, spanning from early practices such as hunting to the advent of agriculture and even industrial farming, has left imprints on the planet's ecology (Ellis, 2021). The imperative to cater to the needs of an ever-expanding global population, surpassing six billion individuals, is propelling extensive alterations across forests, agricultural expanses, water bodies and atmospheric conditions. Recently, substantial expansions in croplands, pastures, plantations and urban areas have occurred on a global scale (Doering and Sorensen, 2018). This growth, while serving to accommodate growing human requirements, has been accompanied by marked escalations in energy consumption, water utilization and fertilizer application, leading to the simultaneous and considerable loss of biodiversity (Foley et al., 2005). Such shifts in land utilization patterns have ushered humanity into a realm where access to a progressively larger fraction of the planet's resources has become unattainable. However, this burgeoning access is weighed against potential threats to ecosystems' capacities to sustain vital functions (Ghajarnia et al., 2020). These functions include facilitating food production, freshwater and forest reserves, regulating climate and air quality, and preventing contagious diseases. Navigating this complex terrain necessitates a delicate equilibrium between the fulfilment of immediate human needs and the safeguarding of the biosphere's intrinsic capability to continue delivering essential products and services over the long term (Foley et al., 2005).

2.8 Hydrological Consequences of Land Use Changes

Deforestation, agriculturalization, urbanization, wetland draining and other types of land use change have all intensified as human populations have grown (Eshleman, 2004). Nearly 50 years, hydrologists have understood that changes in land use can have a significant impact on hydrological processes at all scales. For, from small study plots to hillslopes to entire experimental catchments (Lorentz et al., 2004). Around the turn of the century, research is increasingly being combined with multiscale assessments intended to address both scientific and management challenges at landscape, river basin and regional scales (Steel et al., 2010). Such endeavours are aided by major technological advancements in the collection, interpretation and modelling of hydrological data, as well as new capacities for observing and quantifying land use and land cover changes using remote sensors (Eshleman, 2004). Land-use

changes have significant global impacts on wetland ecosystems, leading to a decline in waterfowl and plant species, and disrupting the delicate balance that supports their biodiversity (Dixon et al., 2016). Variation in wetland water levels has resulted from these changes, which negatively impact wetland species' ability to adapt to changing conditions and affect their reproductive success and overall survival (Li, 2015). Additionally, land-use changes have led to increased flooding peak flows and runoff, inundating wetland habitats and threatening species adapted to specific water levels (Liu et al., 2004). These consequences have significant implications for wetland biodiversity and the survival of important wetland species, which provide essential services such as habitat, water purification, and climate regulation. Understanding the consequences of land-use changes on wetlands is crucial for conservation efforts and sustainable land management practices. Mitigating these impacts should involve habitat restoration, land-use planning, and policies that prioritize the preservation of wetland ecosystems (Liu et al., 2004).

2.9 Gap Analysis

The academic gap in land-use and land-cover changes in the Bangweulu Wetland and surrounding areas is the lack of a comprehensive, integrated assessment that considers the interplay between different factors driving these changes. This research aims to contribute to a holistic understanding of the dynamics at play, by analysing spatial and temporal patterns of land use changes to identify hotspots of change. This study will explore the role of local communities in land-use decisions, evaluating the implications of land-use changes on ecosystem services. By addressing these gaps, this study provides a more comprehensive picture of the challenges and opportunities related to land-use changes in wetlands in particular and in Zambia in general, which can be crucial for developing effective strategies and policies to promote sustainable land management and conservation in the country.

CHAPTER 3: DESCRIPTION OF THE STUDY AREA

This chapter describes the physical and socioeconomic characteristics of the study area. The figure also shows the location of the Bangweulu Wetland and surrounding areas in the Luapula, Northern and Central provinces.

3.1 Location of the Study Area

The research was carried out in the Bangweulu Wetland and its surrounding areas. The Bangweulu Wetland covers approximately 30,000 km² and the surrounding areas, cover 35,158.143 km² (Kamweneshe, 2000). With over 11,900 km² of seasonally flooded plains and permanent swamps, it has one of the largest and most diverse systems in southern Africa. It is similar in size and complexity to the Okavango and Zambezi deltas in Mozambique (Hughes and Hughes, 1992). The study area was defined using a high-resolution (90 meters) Digital Elevation Model (DEM) obtained from DIVA GIS (Hijmans et al 2001). The boundaries were determined based on the location of water flow points around the basin. The study area encompasses parts of Zambia's Luapula and Northern provinces, between 08°S to 18°S and 22° E to 34° E (Figure 1), and its southernmost extremity spans a small portion of the Central Province (Hughes and Hughes, 1992).

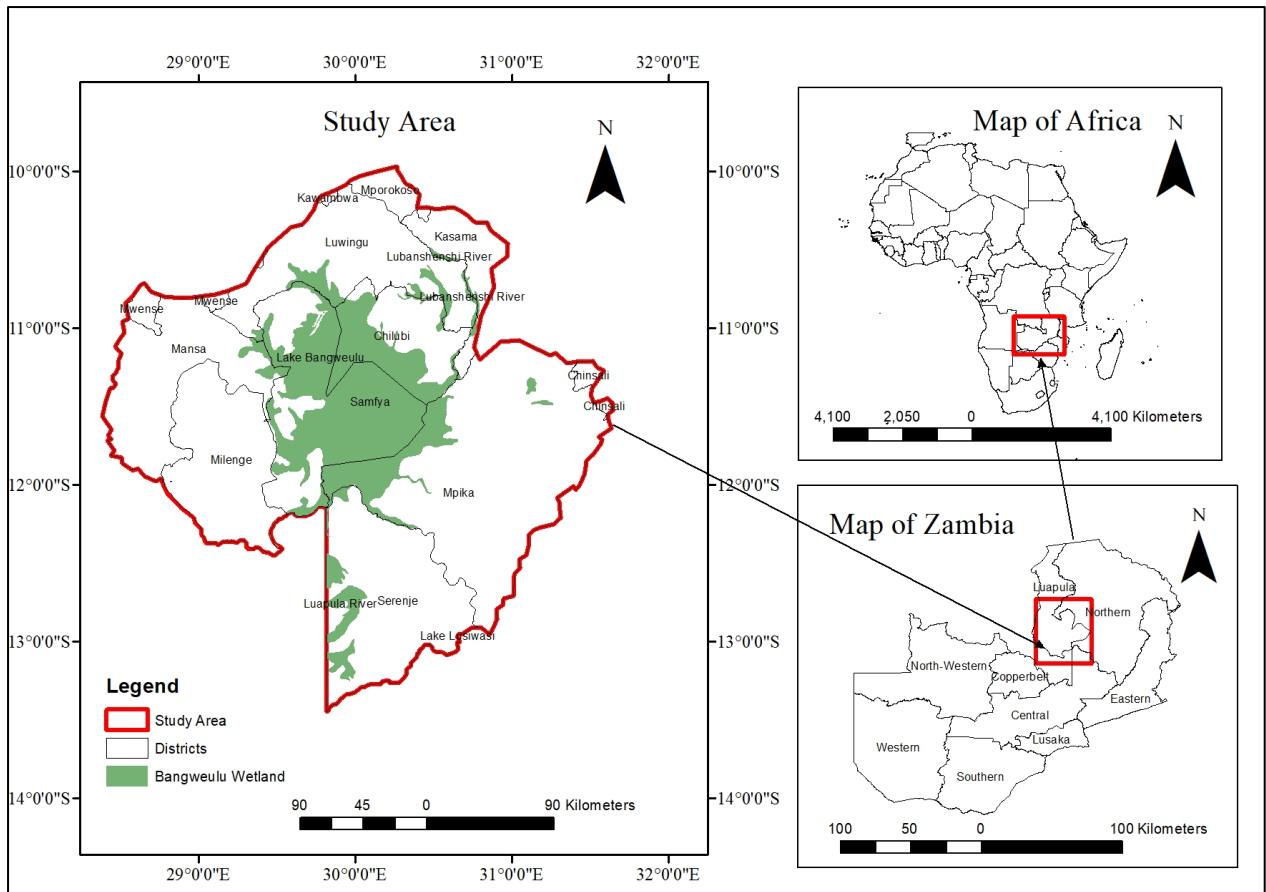


Figure 1: Map showing the location of the Bangweulu Wetland and surrounding areas, Zambia (Lehner, 2020).

3.2 Physical Characteristics

The physical characteristics of the study area include the climate (temperature and rainfall) and hydrology, soils, topography and drainage, vegetation, land use, economic activities and population.

3.2.1 Climate and Hydrology

Three distinct seasons, a cool dry season from April to August, a hot dry season from August to October and a warm wet season from November to April, make up the climate of the Bangweulu Wetland and the surrounding areas. In the Bangweulu Region, the highest and lowest recorded temperatures vary from 19 to 36 °C in October and from 6 to 21 °C in July (Mccann, 2017)) (Figure 2).

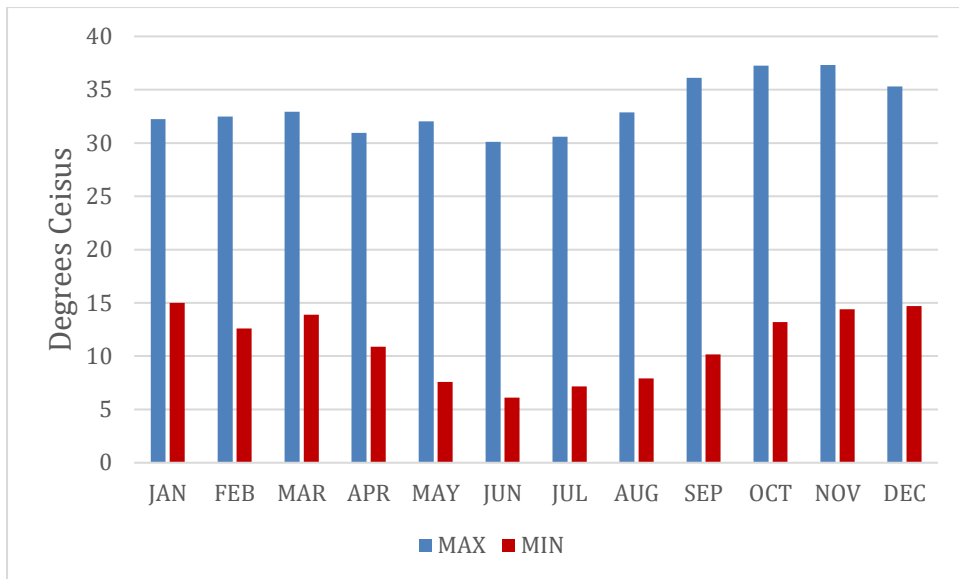


Figure 2: Annual maximum and minimum temperatures of the Bangweulu Wetland and surrounding areas of Zambia (Sparks, 2018). MAX = Maximum temperature; MIN = Minimum temperature.

Over the wetland area, the average annual rainfall is between 800 mm and 1,500 mm with significant year-to-year variation (Kaizen Consulting, 2020) (Figure 3). More than 2,100 mm of water evaporates on average each year.

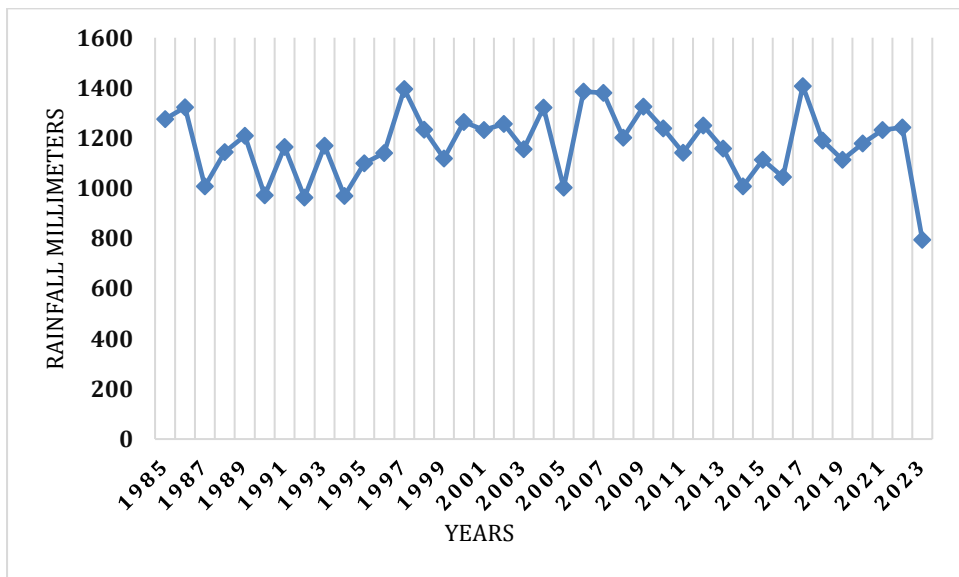


Figure 3: Historical rainfall trends of the Bangweulu Wetland and surrounding areas of Zambia (Sparks, 2018).

The predominant feature of the Bangweulu Wetland is the seasonal flooding regime, which influences every aspect of the local environment and economy. By January each year, vast areas of the Bangweulu Wetland are inundated from local rainfall and runoff. Peak water levels occur in March when the inflow from the Chambeshi and other rivers draining the surrounding catchment spills across the seasonally flooded plains (6,800 km²) and into the permanent deepwater swamps (5,000 km²). Waters recede slowly during the dry season, reaching their lowest level in October/November, leaving only the central basin permanently under water. The mean annual outflow to the Luapula River is approximately 440 m³/s. The extent of floodwater inundation and the rate with which it rises and recedes varies from year to year (Mccann, 2017).

3.2.2 Soil

The Bangweulu Wetland is mostly covered by Arenosols, which are mucky, poorly formed, coarse-textured soils with loam-sand topsoil (Figure 4). These soils are moderately acidic, leach heavily, have a low capacity to retain nutrients and are highly saturable in aluminium. Although certain areas feature Gleysols, which are characterized by mucky, poorly draining, extremely acidic, heavily leached clay soils, they exhibit a moderate to high capacity for retaining nutrients. These soils are moderately to highly saturated with aluminum (Mccann, 2017).

Other parts have Histosols, which are loam topsoils with a high organic matter content that are more than 20 cm thick but less than 40 cm thick in some large, poorly drained dambos and on lake edges.

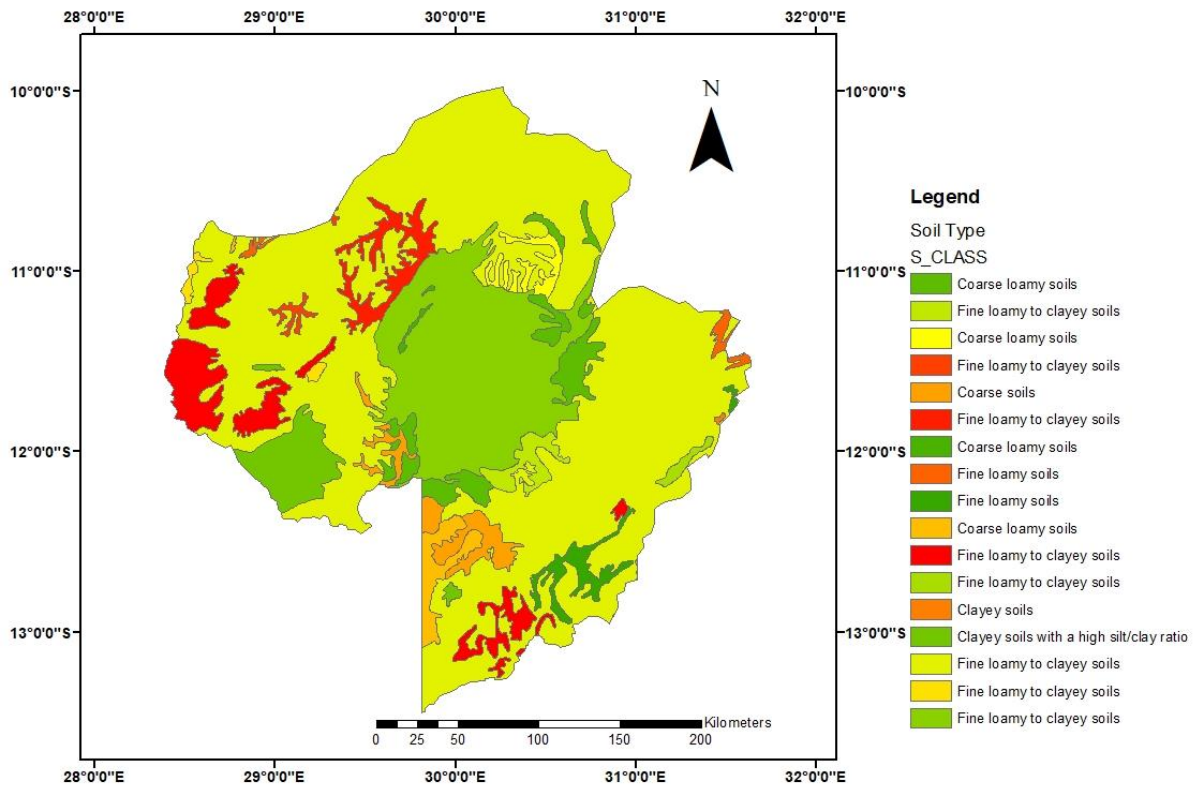


Figure 4: The soil type of the Bangweulu Wetland and surrounding areas of Zambia (Lehner, 2020).

3.2.3 Topography and Drainage

The land elevation across the study area ranges from 1,875 m to 1003 m (Figure 5). The waters of Bangweulu, which fluctuate during the rainy season, cover a triangular area of approximately 9,800 km². The lake, at the northwest corner of the triangle, is 72 km long and 38 km wide (Mccann, 2017).

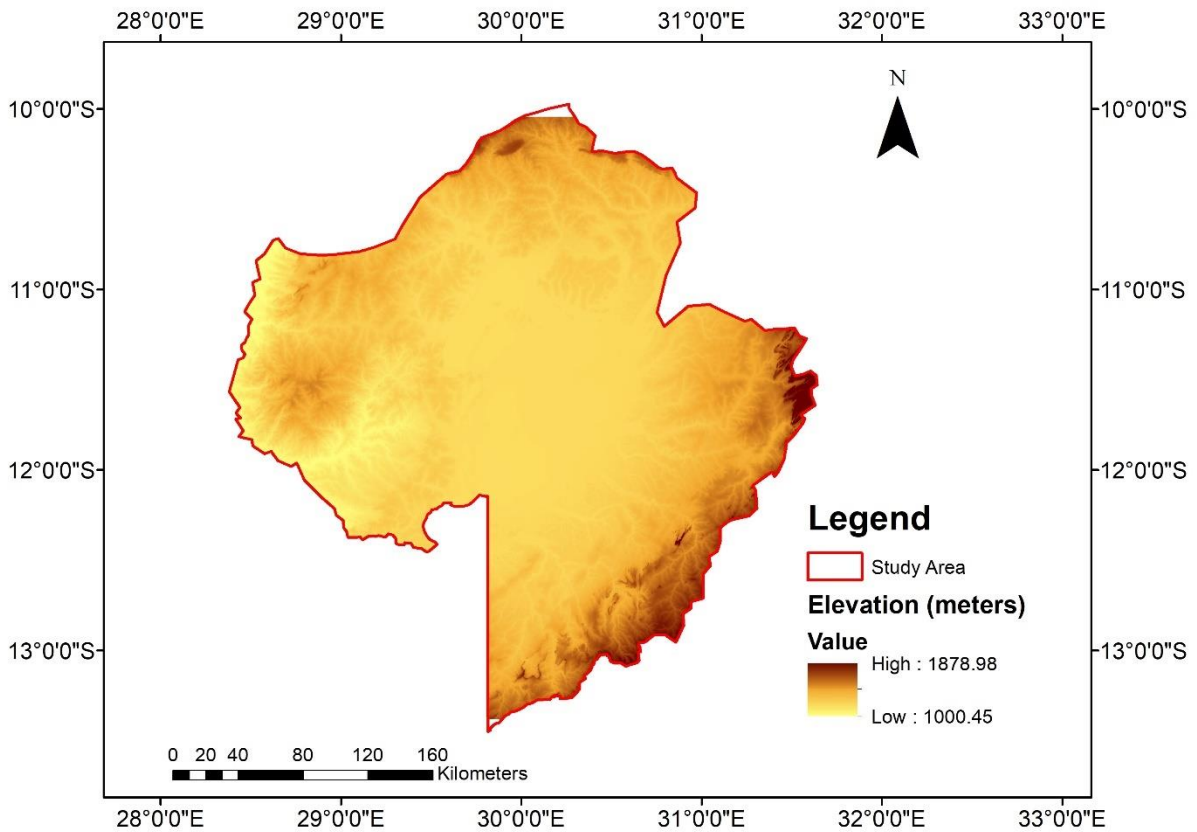


Figure 5: Elevation (m) in the Bangweulu Wetland and surrounding areas of Zambia (Lehner, 2020).

3.2.4 Vegetation

The Bangweulu Wetland is home to a diverse range of vegetation types, with each community influenced by soils and flooding regimes (Kaizen Consulting, 2020). The wetland can be classified into five main vegetation zones: upper mainland, fringing open woodlands, termitaria and fringing grasslands, seasonal floodplains and water meadows/permanent swamp. The upper mainland woodlands are dominated by woody species (Figure 6). A termite zone is found between open woodlands and seasonal floodplains, where termite mounds are created. Within this zone, seasonal floodplains, water meadows, permanent swamps and open water lakes cover the low-lying plain. Emerging vegetation zones occur along the shoreline with grasses and sedges dominating the deepwater floodplain areas (McCann, 2017).

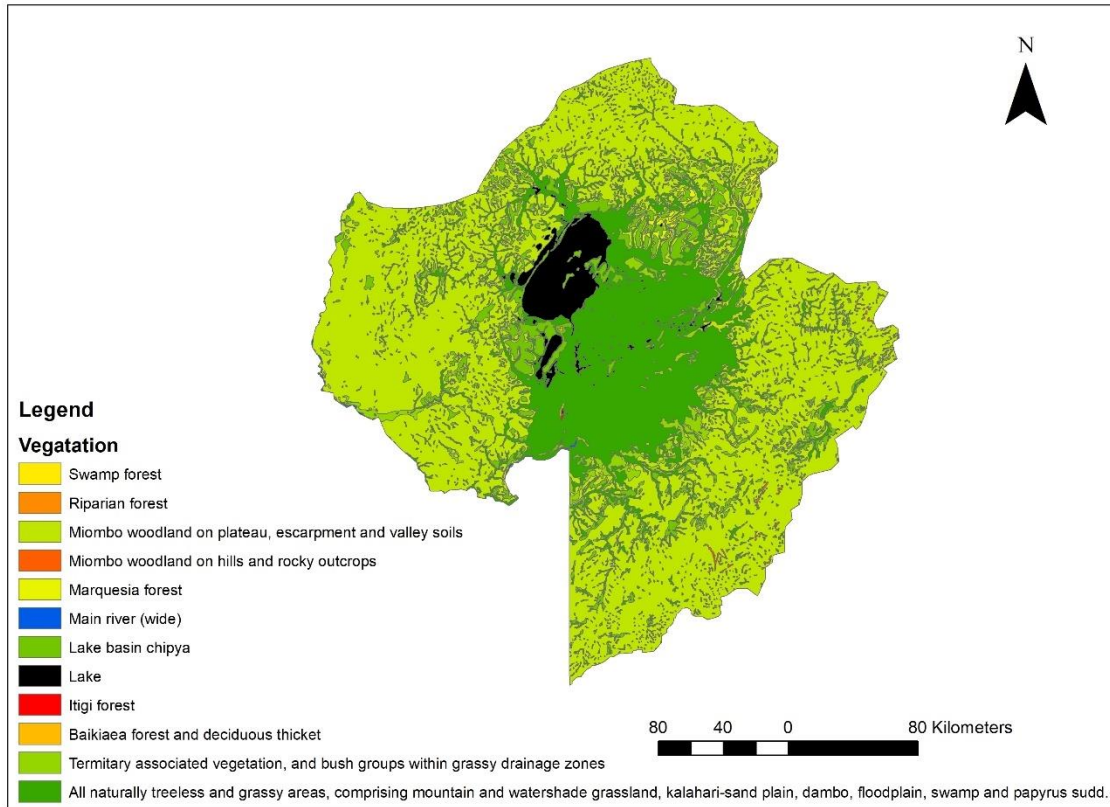


Figure 6: Vegetation in the Bangweulu Wetland and surrounding areas of Zambia (Lehner, 2020).

3.2.5 Economic Activities in the Study Area

The major economic activity in the majority of the sampled areas is fishing and farming, and the area has little industrial activity (Kolding, Ticheler and Chanda, 1996). In terms of agricultural practices, cassava is the most frequently grown crop, (93%), followed by groundnuts, (62%). Finger millet is grown under the Chitemene system in woodlands. Maize has also gained importance, at 78%, especially west of the lake (Chidumayo, 1987). In addition, sweet potatoes, beans, sugarcane and fruits such as citrus and bananas are farmed. However, some households keep goats, sheep, cattle and chickens. Rice, a relatively new crop, is also farmed as of income. Matongo, Bwalya Mponda, Kasoma-Lunga and Kalima Nkonde are known to be the main producing areas in the Samfya District (Central Statistical Office, 1990).

3.2.6 Population

The population of Zambia more than quadrupled from 4,056,955 in 1969 to 19,610,769 in 2022 (Figure 7).

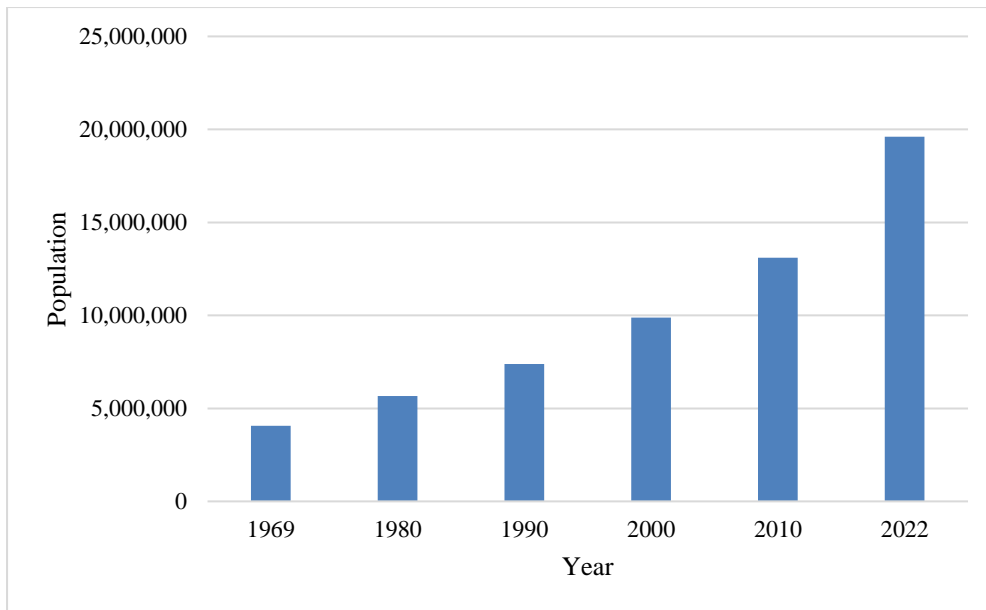


Figure 7: Trends in population size, Zambia 1969-2022 (Central Statistical Office, 2022).

According to the CSO projections, the total population of Luapula Province is 1,514,011, whereas that of Central Province is 2,252,483 and that of Northern Province is 1,618,412. At the district level, of the eight sampled districts (Figure 8), Mansa recorded the highest (327,063), followed by Serenje (158,192), Samfya (147,189), Chilubi (144,011), Chifunabuli (116,326), Mwense (112,605) and Chitambo (100,603), while Chembe recorded the lowest population (51,532 people) (Appendix 1) (Central Statistical Office, 2022)

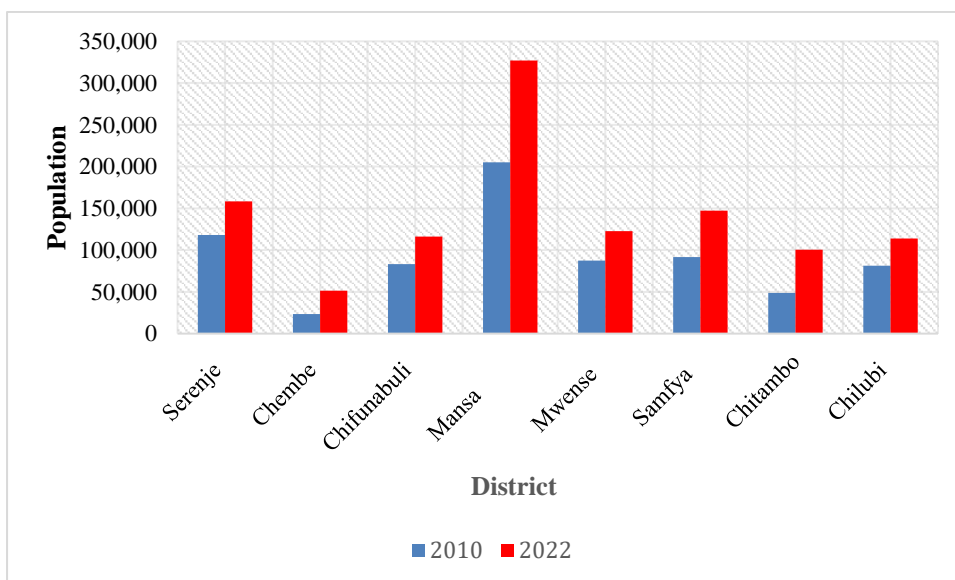


Figure 8: Population density (2010 and 2022) in the Bangweulu Wetland and surrounding areas of Zambia (Central Statistical Office, 2022).

The national population has seen continuous growth in the last decade. Between 2010 and 2022, the population experienced an average annual increase of 3.4%, marking a rise from the 2.8% growth rate observed in the 2000-2010 period. In particular, the rural population exhibited a similar growth rate of 3.4% during the 2010-2022 period, surpassing the 2.1% rate recorded in the preceding period. Conversely, urban areas experienced a decrease in their growth rate, declining from 4.2% in 2000-2010 to 3.5% between 2010 and 2022. Notably, some of the sampled areas highlighted within the red square also displayed the highest average annual growth rate (Figure 9) (Central Statistical Office, 2022).

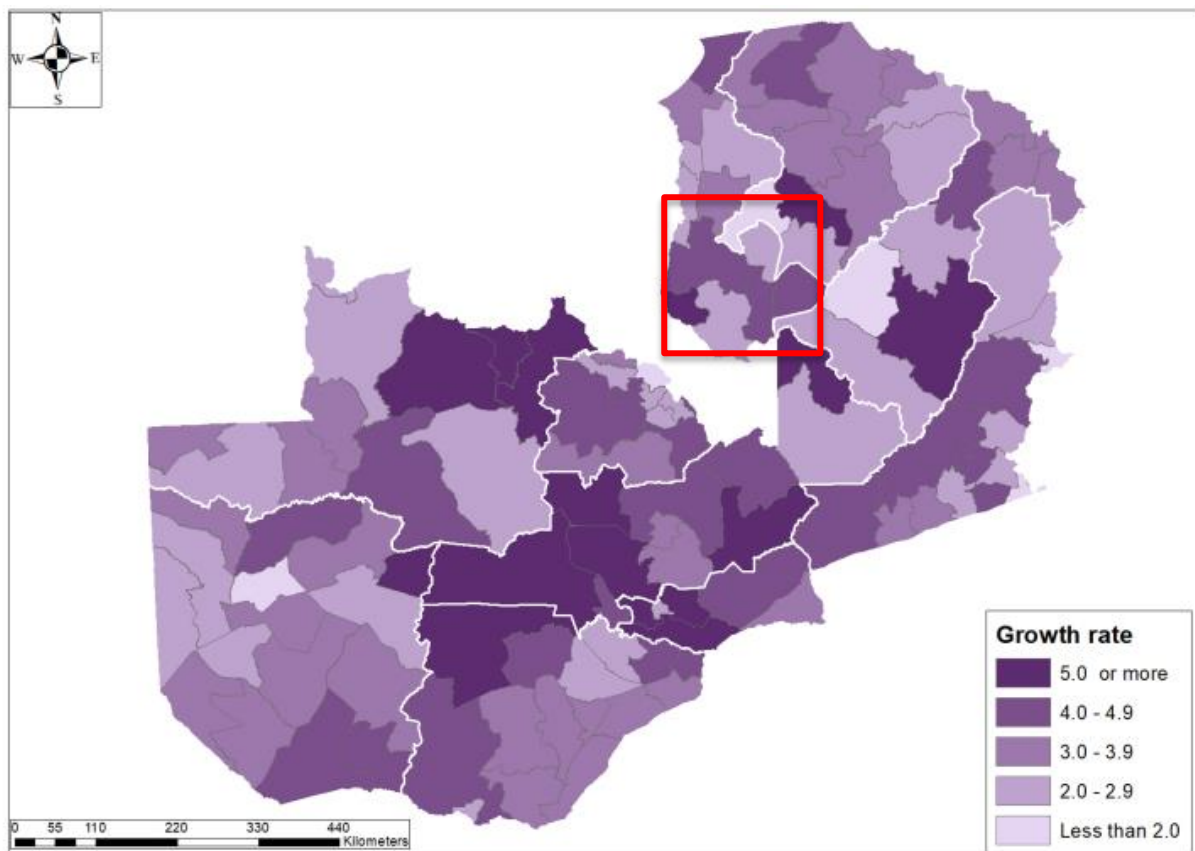


Figure 9: Average annual population growth rate by district, Zambia 2010-2022 (Central Statistical Office, 2022).

CHAPTER 4: METHODOLOGY

This chapter presents the methods used in carrying out this research. It outlines the research approach, sources of data, sampling procedure and analysis.

4.1 Research Approach

This research used household questionnaires, complemented by field observations, remote sensing imagery, key informant interviews, supportive data such as GPS records and related literature (Figure 10).

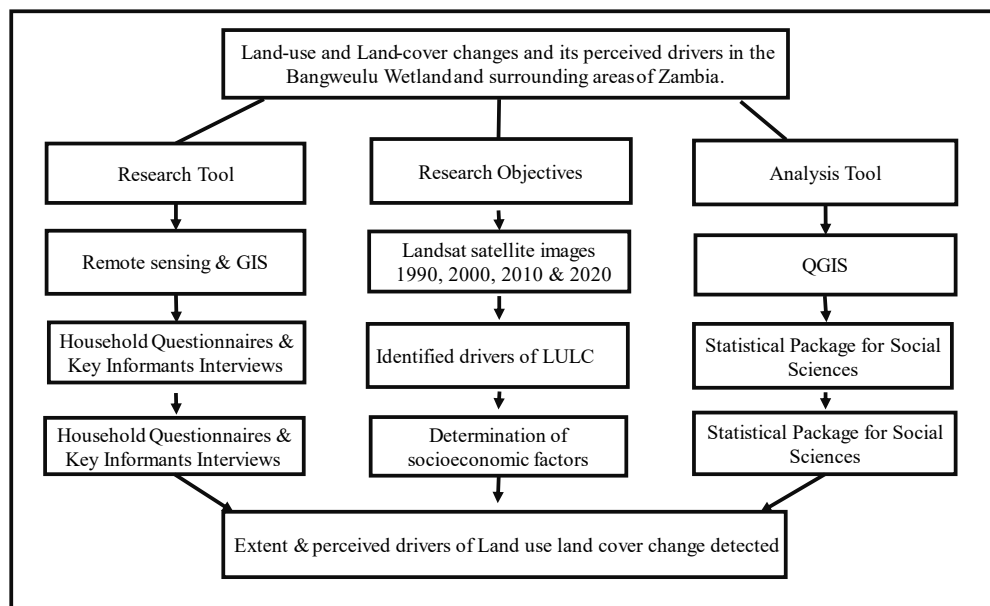


Figure 10: Research and analysis tools used in the study of land use change in the Bangweulu Wetland and surrounding areas. QGIS = quantum geographic information system.

4.2 Primary Data

To understand the dynamics of land use change in the Bangweulu Wetland and surrounding areas, a unique blend of satellite imagery, household questionnaires, targeted interviews with key stakeholders and field observations were utilized (Figure 10 above). The methods of data collection helped to determine how much change has taken place and helped to identify drivers of land use change.

4.2.1 Household Questionnaires

A total of 300 household surveys were administered to the heads of households in the Bangweulu Wetlands. A household, in this context, refers to a group of people who share meals

and living quarters. The head of the household, typically the primary decision-maker, was responsible for completing the questionnaire (Tanzania National Bureau of Statistics, 2011).

This survey instrument aimed to gather data on several key aspects: the history of the Bangweulu Wetland, the current residents, their economic activities and the overall condition of the wetland's resources. Additionally, the questionnaire explored the factors driving changes in land use within the wetland (Appendix 2).

The survey covered a broad range of topics, including demographics, occupation, household composition, income sources, land-use and land-cover changes, population changes over the past 25 years, primary economic activities in the community and residents' perceptions of the causes behind land-use and land-cover changes. This comprehensive data provided valuable insights into local communities' experiences and understanding of the ongoing changes within the Bangweulu Wetland

4.2.2 Key Informant Interviews

The Interviews of the 9 informants were conducted with key stakeholder groups with extensive knowledge of the wetland's history, land-use changes and current conditions. The interviews were conducted with governing body representatives such as district commissioners, agriculture and fisheries officials, traditional leaders and Water Resources Management Authority (WARMA) officials (Appendix 3) to gain a better understanding of the history, factors influencing LULC change and conditions of the Bangweulu Wetland and surrounding areas.

4.2.3 Field Observations

Field observations were conducted through transect walks and field visits. This revealed that major land use activities, such as agriculture, urban development and industrial activities, are dominant in the area. This visual record aids in immediate analysis and serves as a valuable resource for future research (Herrero et al., 2017; Banda et al., 2023). Detailed records were maintained to catalogue the extent and nature of these land use patterns, contributing to a holistic view of the landscape's transformation over time. GPS technology was employed to record ground control points, allowing precise pinpointing and mapping of observed features within the larger landscape.

4.2.4 Sampling Procedure

The Raosoft Random Sample Calculator (www.raosoft.com) was used to determine the sample size. A margin of error of 6% was applied at a confidence level of 94%, with a distribution of 50% of the respondents. Using a 6% margin of error with a 94% confidence level allowed for a slightly smaller sample size compared to what would have been necessary for a 5% error margin with a 95% confidence level. This optimization was important because the research methodology involved not only household surveys but also analysis of satellite imagery. Given that the total number of households in the 8 sampled districts was 1,137,521 households (Central Statistical Office, 2022), the calculated population size was 300. A calculation, greater than 30 (Chakrapani, 2023), indicates a reasonable sample size. As the obtained results can be extrapolated to the entire population of the Bangweulu Wetland and its surrounding areas.

4.2.5 Methods of Sampling and Frequency

The selection of sampling sites considered two key factors. First, proximity to the lake and wetland was prioritized to ensure the sites were directly relevant to the study of these areas. Second, village size was taken into account. Villages with greater physical separation resulted in fewer samples being collected from those areas. A total of 300 household questionnaires were purposively distributed in eight districts: Mwense (10), Serenje (37), Chilubi (50), Chifunabuli (51), Chembe (27), Mansa (42), Chitambo (21) and Samfya (62) (Table 1). In addition, nine key informant interviews were conducted in the Mansa, Samfya, Chembe, Chilubi and Serenje districts (Table 2). The household questionnaires were analysed using the Statistical Package for the Social Sciences (SPSS).

Table 1: Sampled districts in the Bangweulu Wetland and surrounding areas, Zambia.

S/N	District	Number of Sampled Households Per District
1.	Serenje	37
2.	Samfya	62
3.	Mansa	42
4.	Mwense	10
5.	Chifunabuli	51
6.	Chilubi	50
7.	Chembe	27
8.	Chitambo	21
	TOTAL	300

Table 2: Key informant interviews conducted in the Bangweulu Wetland and surrounding areas of Zambia.

S/N	District	Key informants
1	Chembe	District Agriculture Coordinator
2	Chilubi	District Agriculture Coordinator
3	Mansa	District Agriculture Coordinator, Forestry Coordinator, Land husbandry coordinator, Department of Water Resources Development (DWRD)
4	Samfya	District Agriculture Coordinator, Forestry Coordinator
5	Serenje	District Agriculture Coordinator

4.3 Secondary Data

Secondary data were obtained mainly from archival sources (published and unpublished). An extensive review of the literature; both published and unpublished, on the drivers of land use change in wetlands, land use change and its effects on ecosystem services.

4.3.1 Remote Sensing and GIS

250 ground control points consisting of different land use /land cover features and their location points were recorded using a global positioning system (GPS) instrument. Landsat images from 1990, 2000, 2010 and 2020 were freely downloaded from Climate Engines

(<https://app.climateengine.com/climateEngine>), the information obtained was utilized to identify different types of land use /land cover changes in the Bangweulu Wetland and surrounding areas.

4.4 Data Analysis: Imagery Data

This section explores the tools and methods that were used in the analysis in this study.

4.4.1 Acquisition of Satellite Data

Landsat 5 TM (Thematic Mapper) and Landsat 8 OLI-TIRS (Operational Land Imager Thermal Infrared Sensor) images were obtained from Climate Engine via <https://app.climateengine.com/climateEngine>. Climate Engine (ClimateEngine.org) is a web-based application that overcomes many computational barriers users face by employing Google's parallel cloud computing platform, Google Earth Engine, to process, visualize, download and share climate and remote sensing datasets in real-time (Huntington et al., 2017). The shapefile of the study area was overlaid with imagery data downloaded from a climate engine. By overlaying the imagery data with the shapefile, it was possible to create a visual representation of the imagery data for the study area

4.4.2 Detection of LULC Changes using the Maximum Likelihood Algorithm

Classification was performed in QGIS 3.28.0 using the Maximum Likelihood Classification algorithm. Maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class (Soheili et al., 2012). The classification of the areas was performed based on training data for each class. The bands selected for analysis were 4, 3 and 2, and the training areas for each class were processed for the years 1990, 2000, 2010 and 2020. Five distinct classes were used in the classification: Forest, Cropland, Grassland, Settlements and Water (Phiri et al., 2023). These selected classes allowed for a detailed analysis of how human activities like agriculture and infrastructure development might be impacting the wetland area. The following is a description of each class, along with relevant information about the associated vegetation:

- i. Forests: These landscapes primarily consist of mature natural or planted trees and there are no evident indications of significant disruption to ecological processes;
- ii. Cropland: This class represents areas occupied by cultivated crops, fruits and vegetables;

- iii. Grassland: These areas are covered by woody vegetation dominated by young trees and shrubs. They do not undergo cultivation and typically have less than 10% coverage of shrubs and trees;
- iv. Settlement: This class includes areas that comprise human settlements, transportation infrastructure, industrial zones and commercial facilities; and
- v. Water: This class encompasses water surfaces such as rivers, ponds, floodplains, wells or lakes.

4.4.3 Accuracy Assessment using the Confusion Matrix with Ground Truthing Data

The accuracy assessment of land use /land cover maps was conducted using the Confusion Matrix, a widely recognized technique for assessing the performance of land cover classification models (Fonte et al., 2020). A total of 750 ground truthing points were generated to serve as reference data against which the classification results could be compared. The confusion matrix was generated using QGIS 3.28.0 software, enabling the calculation of various accuracy metrics that shed light on the quality of the classification model. The accuracy metrics obtained from the confusion matrix were diverse and comprehensive, allowing for a thorough evaluation of the classification results. The overall accuracy metric measures the proportion of correctly classified pixels in the entire dataset, providing a high-level overview of the model's performance in accurately classifying land cover types across the entire study area. The producer's accuracy quantified the proportion of correctly classified pixels for each individual land cover class, providing insights into the model's strengths and weaknesses for different classes. The user's accuracy assessed the proportion of correctly classified pixels for each land cover class relative to the total number of pixels classified as that specific class, helping evaluate the reliability of the model's predictions for each class. The accuracy metrics obtained from the confusion matrix are mathematically expressed as

$$\text{Overall Accuracy} = \left(\frac{\text{Number of Correct Classifications}}{\text{Total Number of Samples}} \right) * 100\%$$

$$\text{Producer's Accuracy} = \left(\frac{\text{Number of Features of Specific Class Correctly Classified}}{\text{Row Total}} \right) * 100\%$$

$$\text{User's Accuracy} = \left(\frac{\text{Number of Features of Specific Class Correctly Classified}}{\text{Column Total}} \right) * 100\%$$

The combination of these accuracy metrics offered a comprehensive evaluation of the land cover classification model, ensuring the credibility and utility of the generated maps for subsequent analyses and decision-making processes (Foody, 2002). The accuracy of land

cover categorization was evaluated using a confusion matrix and Kappa Index (KI) based on the ground truthing data. The kappa coefficient (k) is expressed mathematically as

$$k = \frac{N \sum_{i=1}^n m_{i,i} - \sum_{i=1}^n (G_i G_i)}{N^2 - \sum_{i=1}^n (G_i G_i)}$$

Where i = Class number; N = Total number of classified pixels; $m_{i,i}$ = Number of pixels in ground truth class i correctly classified as i; G_i = Total number of pixels classified as i; G_i = Total number of pixels in ground truth class i (Munthali *et al.*, 2019).

4.4.4. Quantitative Data Analysis

In this study, the quantitative data collected from the field were analysed using SPSS software (Pallant, 2016). Descriptive statistics, such as frequencies and percentages, were employed to provide a comprehensive description of the data (Glewwe and Levin, 2005). These statistics allowed for a clear understanding of the distribution and patterns of the drivers of land use change, as well as the observed land use change patterns.

Tables and graphs were also created to enhance the presentation and visualization of the data where necessary. These graphical representations facilitated a more comprehensive and accessible interpretation of the findings (Prybutok and Ott, 1989). They provided a visual summary of the key trends and relationships within the data, aiding in the identification of significant patterns and insights. Furthermore, this study utilized the Pearson correlation analysis to assess the strength of the association between the identified drivers of land use change and the observed land use change patterns. Pearson's 'r' is a widely used correlation measure that assesses the linear association between two variables (Schober and Schwarte, 2018). This statistical measure allowed for a quantitative assessment of the relationships between these variables, providing valuable insights into the extent to which the identified drivers influenced the observed land use changes (Pallant, 2016).

Overall, the use of SPSS, descriptive statistics, graphical representations and the Pearson correlation coefficient provided a robust framework for analysing and interpreting the quantitative data, enabling a comprehensive understanding of the drivers of land use change and their relationships with the observed land use change patterns in the study area.

4.4.5 Logistic Regression

Logistic regression analysis was also performed to investigate the variables that contributed to changes in land use and land cover change (LULCC) at the household level in the Bangweulu

Wetland and surrounding areas. Logistic regression is a statistical approach for estimating the chance of an event occurring based on a number of independent factors. In this case, the research aimed to determine how respondents' socioeconomic characteristics (independent factors) affected their assessments of the driving reasons underlying LULCC (dependent variables) (Park, 2013). The logistic regression table presents the coefficients (B), standard errors (S.E.), Wald statistics, degrees of freedom (df), significance levels (Sig.), odds ratios (Exp (B)) and 95% confidence intervals (CIs.) for the odds ratios.

The coefficient (B) represents the estimated effect of each variable on the outcome. A negative coefficient suggests a negative association with the outcome, while a positive coefficient suggests a positive association. The standard error (S.E.) provides information about the precision of the coefficient estimate (Bewick et al., 2005). The Wald Statistic is used to assess the significance of each variable. The degrees of freedom (df) represent the number of independent pieces of information available for estimating the parameter. The significance level (Sig.) indicates the probability of observing a Wald Statistic as extreme as the one calculated, assuming the null hypothesis that the coefficient is zero (Bewick, Cheek and Ball, 2005).

The odds ratio (Exp (B)) represents the change in odds for the outcome associated with a one-unit increase in the predictor variable. A value greater than 1 suggests a positive effect on the odds, while a value less than 1 suggests a negative effect. The 95% confidence intervals (CIs) provide a range within which the true odds ratio is likely to decrease (Sedgwick and Marston, 2010).

The logistic model is specified as:

$$\text{logit}(Y) = \ln\left(\frac{\pi}{1 - \pi}\right) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_k X_{ki}$$

Where β_0 is the intercept and $\beta_1, \beta_2, \dots, \beta_k$ are the coefficients of the independent variables $X_1, X_2 \dots X_k$.

4.5 Ethical Considerations

The study was conducted within the set local ethical guidelines

4.5.1 Ethical Approvals from Relevant Ethics Boards

To ensure ethical conduct, this study received approval from the Natural and Applied Sciences Research Ethics Committee (NASREC) (Appendix 5). Prior to participating in interviews, all

participants were fully informed about the study's objectives and procedures. Their informed consent was obtained to safeguard their rights and privacy.

4.6 Limitations of the Study

This research encountered several limitations that should be considered when interpreting the findings:

1. **Weather Conditions:** Unpredictable weather conditions such as heavy rainfall and extreme heat affected participant availability. To mitigate this, efforts were made to reschedule meetings when necessary;
2. **Low Literacy Rates:** Some participants found it extremely hard to understand what the study was about hence failed to participate in the survey. To address this, researchers provided thorough explanations with the assistance of village headmen;
3. **Limited Access to Updated Secondary Data:** Accessibility to the most recent secondary data from relevant stakeholders was a challenge due to inadequate systems. As a mitigation strategy, the study relied on the available data; and
4. **Challenges in Assessing Certain Study Sites:** The inability to fully assess specific study sites was a limitation because certain sites could only be assessed using boats. Researchers addressed this by utilizing boats to access these sites.

CHAPTER 5: RESULTS

This chapter is based on the study's findings according to the objectives of the study.

5.1 Overall Trend Analysis of LULC (1990–2020)

The analysed imagery data in Figure 11 show the extent or area covered by different land cover categories (water, forest, grassland, settlement and cropland) for four specific years: 1990, 2000, 2010 and 2020. The proportionate coverage area of each of the five classes extracted in the Bangweulu Wetland and surrounding areas from 1990 to 2020 of LULC trends is summarized in Appendix 4. Over the past 30 years, grassland, forests and water cover decreased due to deforestation, urbanization and other land-use changes, while cropland and settlement areas expanded (Figure 12). These findings offer valuable insights into the change trends of different LULC classes within the study area.

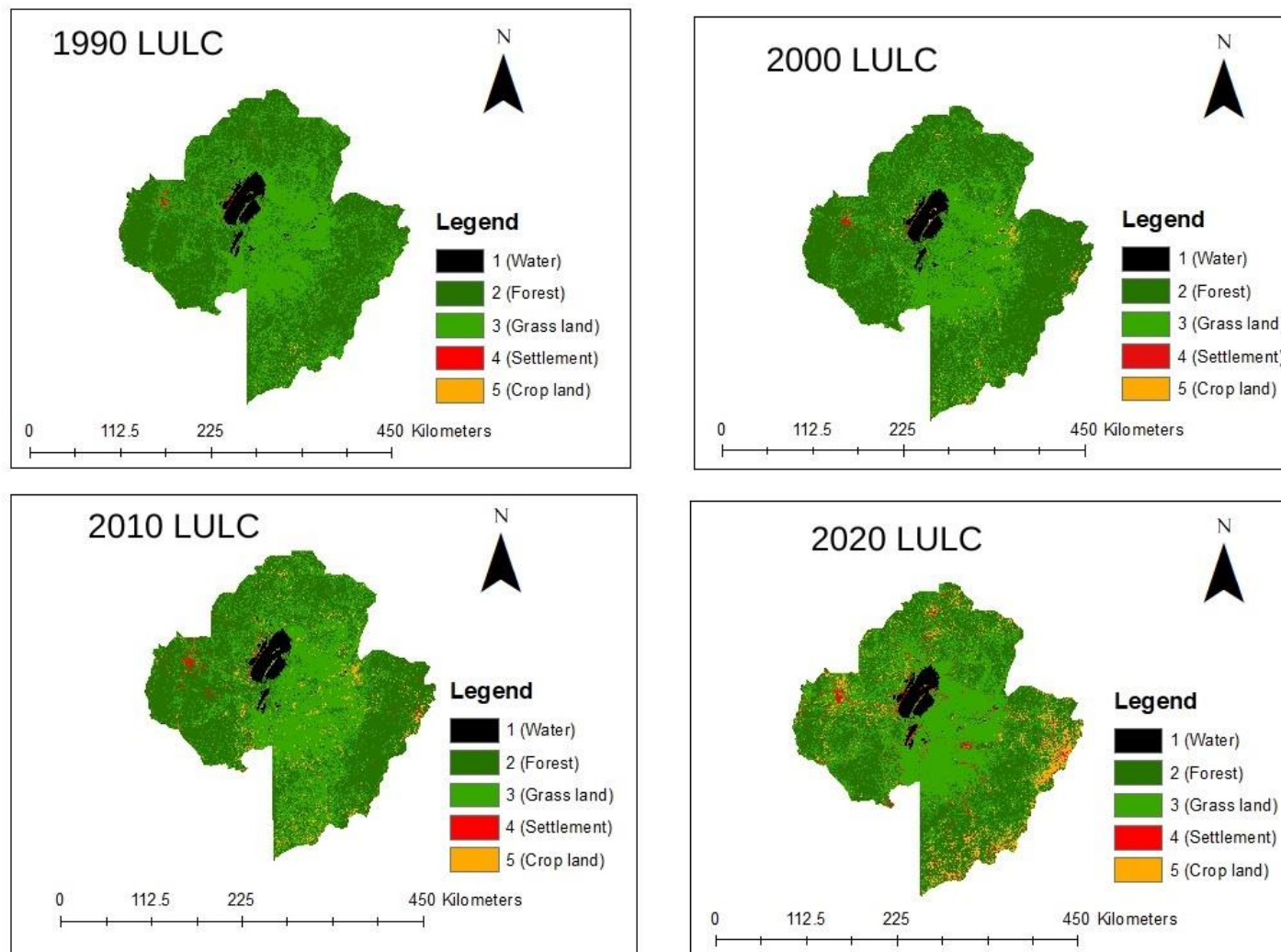


Figure 11: LULC maps for 1990, 2000, 2010 and 2020 in the Bangweulu Wetland and surrounding areas of Zambia.

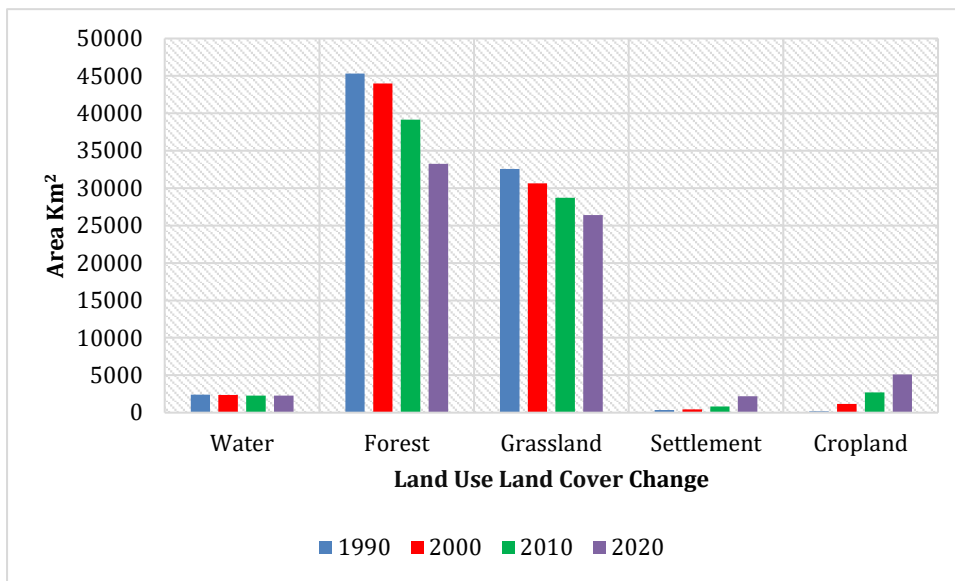


Figure 12: Trends of land use changes in the Bangweulu Wetland and surrounding areas between 1990 and 2020 of Zambia.

The results show that over the years, the water area decreased from 2410.72km² in 1990 to 2278.31 km² in 2020. On the other hand, the forest area consistently decreased from 45298.93 km² in 1990 to 33233.52 km² in 2020, indicating significant deforestation and land-use changes.

The grassland area also showed a consistent decline, from 32557.91 km² in 1990 to 26418.23 km² in 2020, suggesting conversion to other land uses. In contrast, the settlement area has continuously increased, expanding from 356.69 km² in 1990 to 2210.38 km² in 2020, indicating rapid urbanization. Additionally, the cropland area has experienced a substantial increase, growing from 165.27 km² in 1990 to 5108.13 km² in 2020, likely to meet agricultural demands.

5.1.1 Accuracy Assessment of Land Use Land Cover Change (1990 - 2020)

The classified images have an overall accuracy of more than 86%, resulting in a reliable LULC classification above 80% (cf. Ruppert, Hussain and Müller, 2016). Furthermore, the overall Kappa Coefficient for all the classified images ranged between 0.87 and 0.94, which when compared to Landis and Koch, (1977) ratings shows that the classification carried out for the study has strong agreement with the ground-truthing reference data.

The Kappa Coefficient is a measurement of the precision or agreement between data from classified imageries and data from ground reference locations (Foody, 2020). Although there

were small differences in producer accuracy (PA) and user accuracy (UA) of specific LULC categories, the classifications exhibited high overall accuracy (Table 3). These accuracy assessment results provided the basis for subsequent examination of LULC changes.

Table 3: Accuracy assessment results for (1990 - 2020) LULC maps in the Bangweulu Wetland and surrounding areas, Zambia. PA = producer accuracy; UA = user accuracy.

Class	2020		2010		2000		1990	
	PA	UA	PA	UA	PA	UA	PA	UA
Water	0.97	1.00	1.00	1.00	0.97	1.00	1.00	1.00
Forest	0.81	0.97	0.86	1.00	0.91	0.97	0.88	0.97
Grass land	0.88	0.97	0.78	0.93	0.91	1.00	0.81	1.00
Settlement	0.96	0.80	1.00	0.90	1.00	0.91	1.00	0.83
Crop land	1.00	0.83	0.91	0.67	1.00	0.92	1.00	0.83
Overall Accuracy	0.91		0.90		0.95		0.93	
Kappa	0.89		0.87		0.94		0.90	

5.2 Perceived Drivers of LULC change in the Bangweulu Wetland and surrounding areas

As previously indicated, 300 local communities were surveyed to identify the main drivers of land use and land cover change in the Bangweulu Wetland and surrounding areas. Participants were asked to rank the factors they believed were contributing to these changes on a scale of 1 to 5, with 1 being the least significant and 5 being the most significant. The factors highlighted in red (population growth, agricultural activities, settlements and the ecosystem services decline) (Figure 13) are emphasized as the primary causes of the observed LULC changes in the Bangweulu Wetland and surrounding areas. This ranking helped to identify the relative importance of each driver and provided valuable insights into the human activities that are directly transforming the land cover in this region.

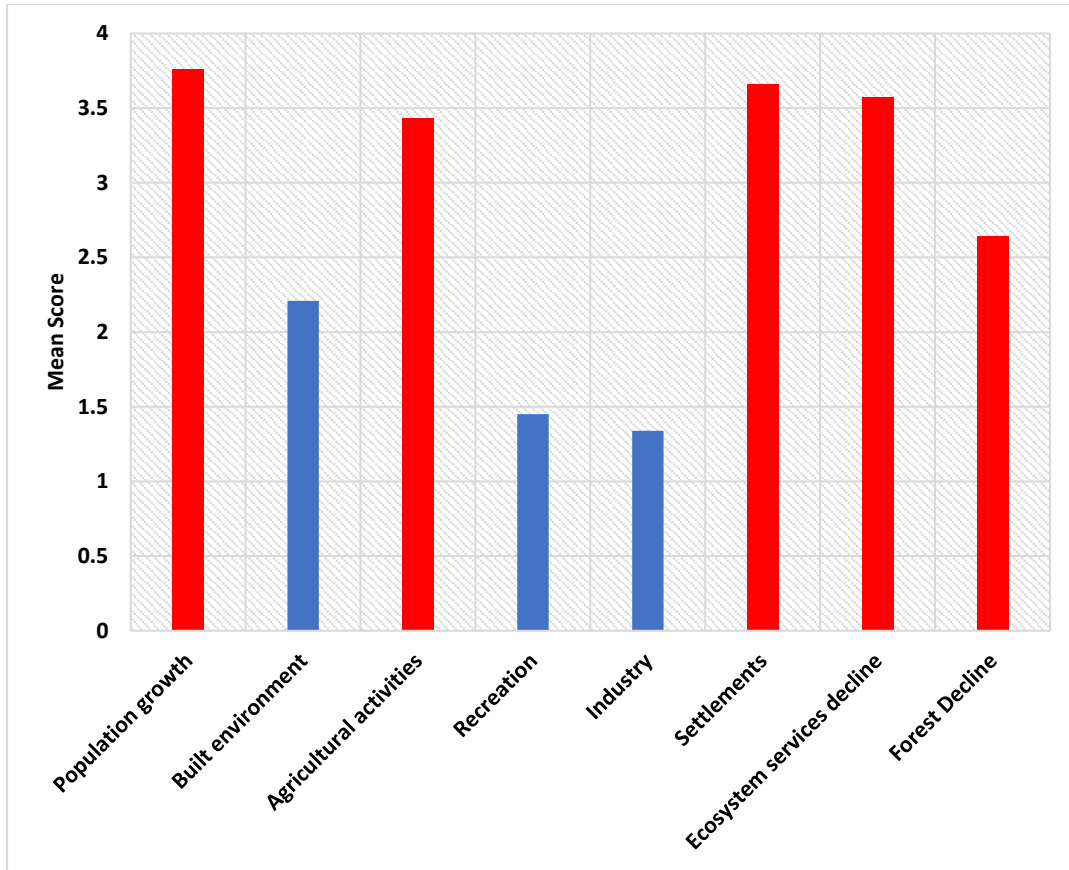


Figure 13: Perceived drivers of land use change in the Bangweulu Wetland and surrounding areas of Zambia.

5.2.1 Population Growth

The findings revealed population growth as a leading driver, with the highest average score of 3.76 out of 5. A substantial score indicates that the growing number of people living in and around the wetland has a profound impact on the alteration of land use patterns.

The demographic data collected from the surveys also revealed a high rate of in-migration, with 56% of respondents reporting that they had migrated to the Bangweulu Wetland from other regions of Zambia (Table 4). The Central Statistical Office (2022) reported that the population of Luapula in 2022 will increase to 1,514,011, showing a growth of over 52.6% from 991,927 in 2010, hence supporting population growth as a driver of change in the study area. The reasons stated by participants are listed in Table 4, accompanied by their respective frequencies and percentages, illustrating the frequency of mention for each reason.

Table 4: Respondents' reasons for migrating to the Bangweulu Wetland and surrounding areas of Zambia.

	Frequency	Percent
Marriage	29	9.7
Farming	30	10
Employment	60	20
Fishing	18	6
Just for change of place	64	21.3
Born here	99	33
Total	300	100

5.2.2 Settlements

The settlements had a mean score of 3.66 from 5, indicating that the establishment and expansion of human settlements in wetland areas play a significant role in driving land use change. The presence of settlements has been observed to result in the alteration of land use patterns within the Bangweulu Wetland.

5.2.3 Ecosystem Services Decline

The ecosystem services (ES) decline had a mean score of 3.57 from 5, indicating that it is recognized as a significant factor influencing land use land cover change in the Bangweulu Wetland and surrounding areas.

5.2.4 Agriculture

Agricultural practices were also identified as a major driver of land use change with a mean score of 3.43 out of 5 from participants indicating its significance. The expansion of farming and livestock grazing has significantly impacted land cover and land use within the Bangweulu Wetland, leading to the loss of natural vegetation and disruptions in hydrological patterns.

5.2.5 Forest Decline

Forest decline had a score of 2.64 from 5, indicating that the reduction in forest cover is also recognized as a factor influencing land use change. Forests provide essential ecosystem services and play a significant role in regulating the hydrological cycle, maintaining biodiversity and providing habitats for various species.

At the other end of the spectrum, the drivers of land use change with mean scores below 2.5 were the built environment, recreation and industry. The built environment, with a mean score of 2.21, refers to the construction of infrastructure including roads, buildings and other human-made structures. Although this driver has a moderate impact, it is comparatively less significant than others in terms of altering land use within the wetland. A mean recreation score of 1.45, indicates that activities such as tourism and leisure activities have a relatively low influence on land use change in the Bangweulu Wetland. Similarly, industry, with a mean score of 1.34, suggests that industrial activities have a minimal impact on altering land use patterns within the wetland.

To reveal a significant relationship between land use change and various factors, Pearson correlation analysis was performed. The results presented in Table 5, reveal a statistically significant difference ($p < 0.05$). Specifically, the significance coefficients were as follows: 0.000 for forests; 0.000 for settlements; 0.000 for ecosystem decline; 0.000 for population; and 0.041 for agriculture. These coefficients demonstrate that there is a statistical association between the occurrence of land use change in the wetland and forest decline, settlements, ecosystem services decline, population growth and agricultural activities, as all the values were below 0.05.

Table 5: Pearson Correlations between Land Use Change and Drivers in Bangweulu Wetland and surrounding, Zambia. Correlations are significant at the 0.05 level (2-tailed); N = number of participants.

Correlations

	Observed land use change	Forest decline	Settlements	Ecosystem services decline	Population growth	Agricultural activities
Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.041
Correlation	1	-0.313**	-0.301**	-0.282**	-0.240**	-0.118*
N	300	300	300	300	300	300

5.3 Logistic Regression Analysis of Perceived Variables of Drivers of LULC change

The data presented in Table 6 provides the results of a logistic regression analysis, where the variables indicate that the length of residence in the wetland had a substantial influence on perceptions of the local community. The amount of time an individual had lived in the neighbourhood, in particular, was found to have a statistically significant ($p < 0.05$) effect on views of population increase and agricultural expansion as drivers of LULC change. The longer people stayed in the region, the more likely they were to see population increase and agricultural development as major drivers of LULC change. Furthermore, among the key socioeconomic drivers, people whose primary economic activity was farming, were likely to experience significant effects of LULC change and its drivers in the community.

Table 6: Results of logistic regression analysis in the Bangweulu Wetland and surrounding areas of Zambia. B = Coefficients; S.E. = Standard errors; Wald statistics; df = degrees of freedom; Sig. = significance levels; odds ratios (Exp (B)) and 95% confidence intervals (CIs) for the odds ratios.

	B	S.E.	Wald	Df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
How long have you lived in the community	2.911	0.775	14.107	1	0.000	18.37	4.022	83.898
Farming as main economic activity	1.559	0.752	4.3	1	0.038	4.756	1.089	20.769
Constant	1.019	0.319	10.176	1	0.001	2.771		

The results in Table 7 show the outcomes of binary regression analysis between the response of LULC on the Bangweulu wetland and perceived drivers. The analysis also revealed LULC was significantly influenced by population increase, ecosystem services decline, forest decline, agricultural activities and settlements (based on p -values < 0.05). While, built environment, recreation and industry don't have statistically significant relationships with LULC change (based on p -values > 0.05).

Table 7: Binary regression analysis between the response of LULC on the Bangweulu wetland and LULC drivers.

	B	S.E.	Wald	Df	Sig.	Exp (B)
Population Growth	0.59	0.205	8.252	1	0.004	1.804
Bulit Environment	-0.449	0.237	3.609	1	0.057	0.638
Recreation	0.085	0.302	0.08	1	0.777	1.089
Agricultural Activities	-0.428	0.179	5.7	1	0.017	0.652
Industry	0.091	0.182	0.251	1	0.616	1.096
Settlements	-0.706	0.283	6.225	1	0.013	0.493
Ecosystem Services Decline	-0.479	0.234	4.181	1	0.041	0.619
Forest Decline	-0.424	0.156	7.441	1	0.006	0.654
Constant	8.149	1.321	38.029	1	0.000	3460.539

5.4 Socioeconomic Determinants of Perceived Drivers

Based on the provided information, the socioeconomic determinants of the perceived drivers of land use change in the Bangweulu Wetland and surrounding areas are described here.

5.4.1 Socioeconomic Status and Livelihood Strategies

According to the data acquired from the analysed findings, population increase is a significant driver of land use /land cover change in the study area, with a high rate of migration identified as one of the reasons for population growth in the examined areas. Migrations were due to education, outsourcing, fishing and farming, implying that socioeconomic issues play a significant role in influencing people's decisions to migrate to wetlands and engage in certain livelihood practices.

The research revealed that the establishment of fishing camps by mobile fishermen also emerged as a key determinant of land use change in the wetland because it involves the relocation of fishermen together with their families from their permanent residences to temporary campsites near the water, often leading to the construction of small dwellings to accommodate increased populations. This shift has resulted in a significant growth of approximately 50,000 people residing within the wetland area (cf. African Parks, 2008).

Economic possibilities and the need for improved living conditions all contribute to an increase in settlement and agricultural activity, which leads to changes in land use patterns. The results in Figure 14 shows the participants' reactions to the probable causes of population growth. The results indicate that 56% of the participants attributed that a significant proportion of the population increase was due to individuals and families relocating to the wetlands from other

areas. Furthermore, 34% of the participants identified a high birth rate as a cause of population growth. This further indicated that a substantial portion of the population increase can be attributed to natural population growth resulting from a greater number of births. On the other hand, 7% of the participants were unsure about the causes of population growth and 3% indicated that there had been no change in the population.

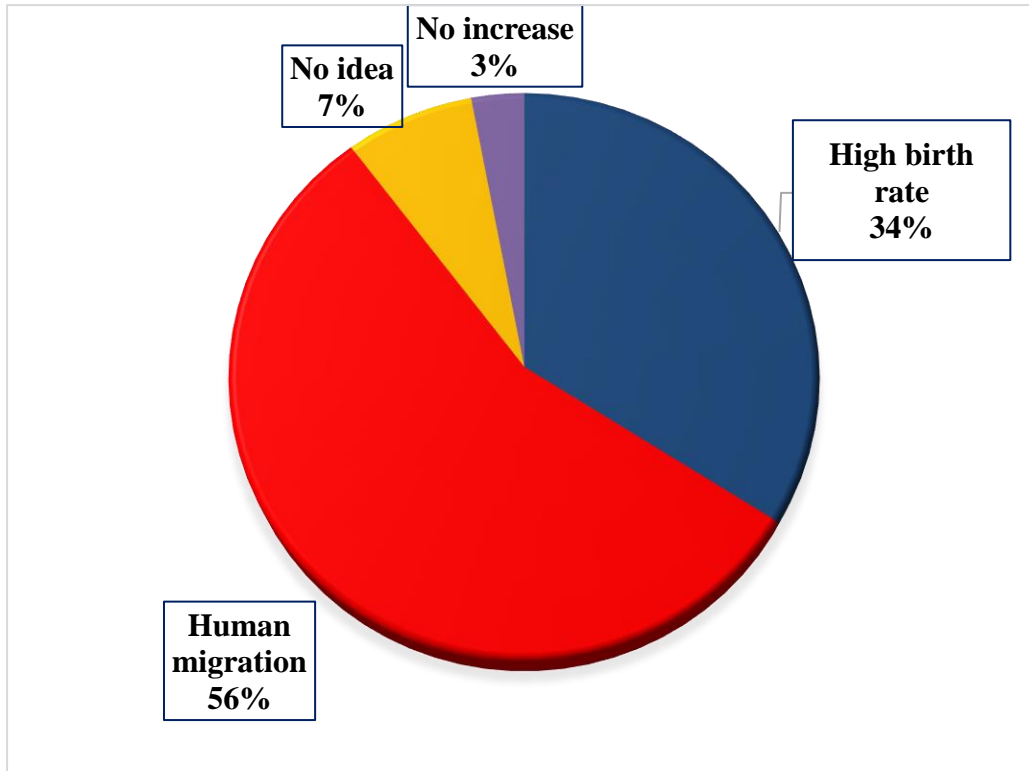


Figure 14: Participants' response to potential causes of change in the Bangweulu Wetland and surrounding areas of Zambia.

To validate that the high birth rate was a cause of population growth, Figure 15 reveals that more than 51% of the 300 interviewed households were responsible for providing food for five or more people. Some households were reported to have more than 15 dependents, further suggesting that the wetland area experienced significant population growth due to a high number of births. Furthermore, Table 8 highlights that approximately 46% of the respondents had lived in the area for less than 25 years. Hence, supporting the response of people moving to the area as a major contributor to population growth (as indicated by 56% of participants). The relatively large percentage of respondents who recently migrated to the area suggests that

migration plays a significant role in driving population growth in the Bangweulu Wetland and surrounding areas.

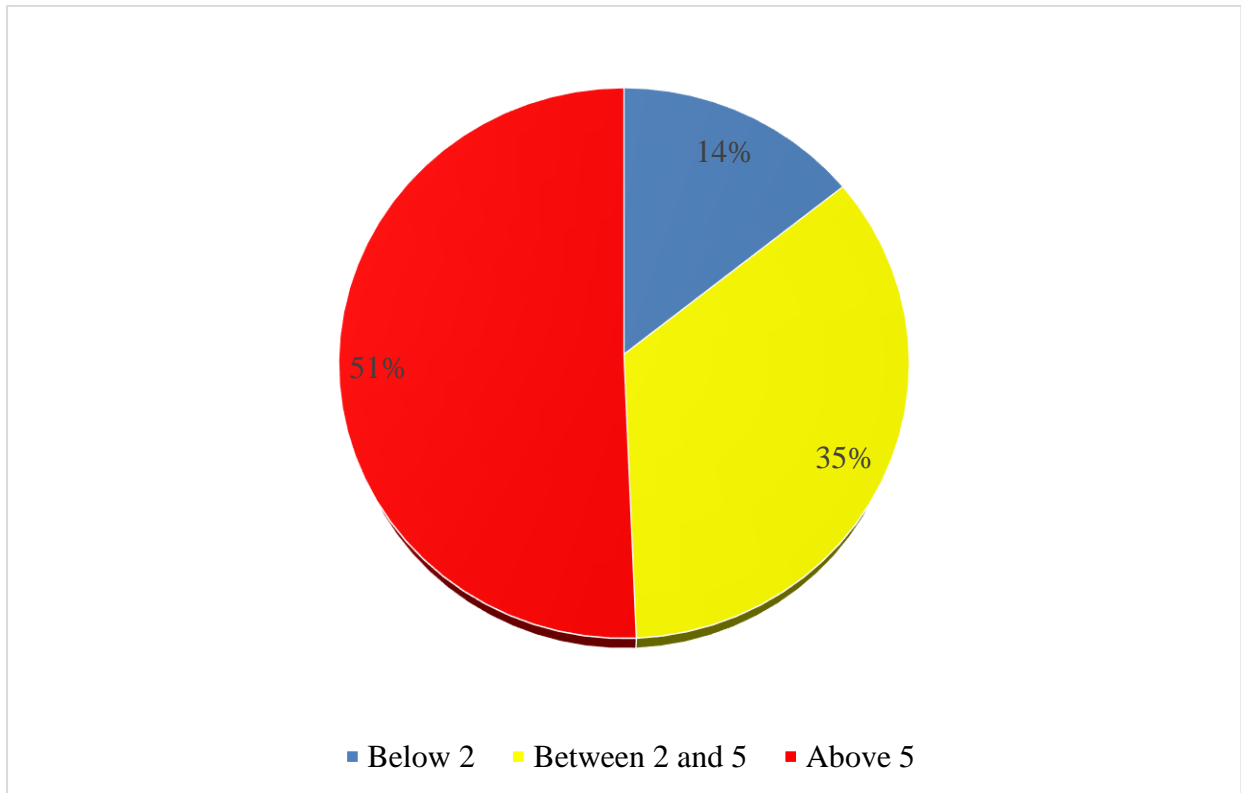


Figure 15: The participants' household sizes in the Bangweulu Wetland and surrounding areas of Zambia.

Table 8: How long the participants have lived in the Bangweulu Wetland and surrounding areas of Zambia.

	Frequency	Percent
Below 5yrs	62	20.7
Between 5yrs and 25yrs	78	26
25yrs and above	65	21.7
Born here	95	31.7
Total	300	100

The responses obtained from the participants regarding the reasons for people moving to the Bangweulu Wetland are presented in Table 9. This information offers valuable insights into the factors that attract individuals or families to relocate to the region. The table includes a list

of reasons along with corresponding frequencies and percentages indicating how frequently each reason was mentioned by the participants.

Table 9: Respondents' reasons for migrating to the Bangweulu Wetland and surrounding areas of Zambia.

	Frequency	Percent
Marriage	29	9.7
Farming	30	10
Employment	60	20
Fishing	18	6
Just for change of place	64	21.3
Born here	99	33
Total	300	100

5.4.2 Agricultural Development and Market Demands

The expansion of farming practices and livestock grazing were strongly associated with the increase in market demand for cash crops such as rice, cassava, groundnuts and maize due to agricultural development initiatives and advancements in agrotechnology. The responses obtained from participants regarding the main economic activities in the sampled districts are detailed in Table 10. The findings illustrate the percentage distribution of respondents' answers, highlighting the predominant economic activities in these districts.

Table 10: The main economic activities in the sampled districts in the Bangweulu Wetland and surrounding areas of Zambia.

	Frequency	Percent
Farmer	148	49.3
Business	48	16
Craft Work	15	5
Construction	2	0.7
Fishing	41	13.7
Formal Employment	40	13.3
Domestic Work	6	2
Total	300	100

According to Table 9 above, farming emerged as the economic activity, with the highest score, accounting for 49.3% of the responses. This result underscores the significance of agriculture as a primary economic driver in the surveyed districts. This finding suggests that a substantial portion of the population is engaged in farming activities, highlighting the importance of the agricultural sector in generating livelihoods and contributing to local economies. Fishing, with a score of 16%, was identified as another significant economic activity in the surveyed districts. The importance of fishing as a source of income and sustenance for communities residing near water bodies such as Lake Bangweulu for fishing plays a crucial role in supporting local food security, trade and employment opportunities.

The "business" category received a score of 15%, indicating the prevalence of entrepreneurial activities in the surveyed districts. A range of businesses, including small-scale enterprises (kiosks), shops, services and trading activities, contribute to local economic growth and employment generation. Formal employment, scoring 14%, suggests that a portion of the population is engaged in wage -based employment in various sectors, such as the government, private companies or formal institutions. Occasional jobs, with a score of 6.5%, refers to temporary or part-time employment opportunities in which individuals engage in intermittently. These jobs include casual labour, seasonal work, or short-term contracts. The category of domestic workers, scoring 2.5%, suggests that a small percentage of respondents are engaged in domestic service or work as household help for other families. Construction, was scored as 1%, indicating that a minimal percentage of respondents identified construction-related activities as a significant economic driver.

5.4.3 NGO Projects and Development Programmes

Nongovernmental organizations (NGOs) and other stakeholders play essential roles in promoting agricultural development not only in Luapula Province but also in Zambia as a whole. Various projects aimed at enhancing the capacity and capabilities of farmers have contributed to increased engagement in farming activities. These development programmes and projects align with socioeconomic goals of improving livelihoods, income and food security, which, in turn, influence land use patterns within the wetland.

The findings from the interviews with the nine key informants revealed an increase in market demand for cash crops, specifically rice, cassava, groundnuts and maize in Luapula Province. This increase in demand was attributed to the advancement of programmes that support agrotechnology and encourage more people to engage in farming activities. These initiatives

have been instrumental in promoting agricultural development and improving the productivity of farmers in the region.

During an interview with the Samfya District Agricultural Coordinator, it was reported that the increased engagement in farming is attributed to various projects initiated by nongovernmental organizations (NGOs). These projects have played a crucial role in enhancing the capacity and capabilities of farmers in Luapula Province. As a result, Chembe District has achieved self-sufficiency in rice production, which is a significant milestone for local agricultural development.

A comprehensive list of the programmes and projects implemented in the district is provided in Table 11. The implementation of these programmes and projects highlights the collaborative efforts of various stakeholders, including nongovernmental organizations and local authorities, to advance agricultural development across Zambia.

Table 11: Some of the programmes that have been undertaken in the Bangweulu Wetland and surrounding areas of Zambia.

S/N	PROGRAMME
1.	Farmer input and response support intensive
2.	Promote sustainability agriculture, soil conservation and water conservation (2009 to 2011)
3.	Conservation agriculture scaling up (2012 to 2016)
4.	Programme for Luapula agriculture and rural development (2009 to 2015)
5.	Rice development programme under JICA (2016 to 2018)
6.	Small holder productivity promotion programme (2012 to 2018)
7.	Transforming landscapes for resilience of development (2018 to date)

5.4.4 Energy Sources and Charcoal Burning

The decline in forest cover, a critical environmental concern widely acknowledged for its role in shaping land use patterns, has been attributed to the widespread practice of charcoal burning. Charcoal burning was a dominant determinant in influencing this practice for approximately half of the 300 sample households who lacked access to electricity (Figure 16). This socioeconomic factor sheds light on the relationship between energy sources and land use dynamics, specifically highlighting how the heavy reliance on charcoal for cooking purposes is fundamentally rooted in the absence of viable energy alternatives. The repercussions of this

dependence on charcoal reverberation through the landscape, significantly impact the delicate ecosystem of wetlands and their associated forest resources.

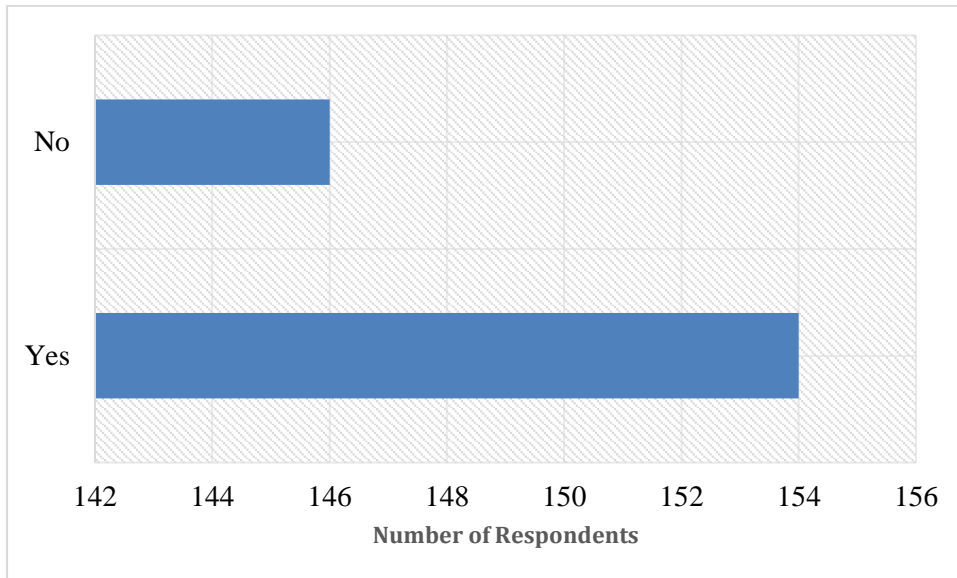


Figure 16: Respondents response to whether they are involved in charcoal burning in the Bangweulu Wetland and surrounding areas of Zambia.

In summary, socioeconomic determinants such as livelihood strategies, agricultural development, NGO projects and energy sources influence the perceived drivers of land use change in the Bangweulu Wetland and surrounding areas. These factors highlight the interactions between human activities, economic considerations and environmental changes that shape land use patterns in the region

CHAPTER 6: DISCUSSIONS

This section discusses all the results generated according to the objectives of the study.

6.1 LULC Change between 1990 and 2020 using Landsat Satellite Images

The current study had an overall accuracy (over 86%) and Kappa coefficient values (between 0.87 and 0.94). Roy et al., (2015) achieved similar levels of accuracy in their land cover and land use classification, with most classes exceeding 90% accuracy. Muche et al., (2023) in northeastern highlands Ethiopia also reported similar accuracies for 1984, 1991, 2001 and 2021, and the overall categorization accuracies ranged from 87% to 91%, revealing a very strong agreement between the categorized images and the ground truth data.

Satellite imagery analysis showed changes in land cover (water, forest, grassland, settlements, and cropland) in the Bangweulu Wetland and surrounding areas from 1990 to 2020. These findings are similar to those of Nkolokosa et al., (2023) in Malawi, who observed substantial changes in land cover and land use over a 30-year period. Built-up areas expanded by 209%, while bare land and cropland increased by 10%. In contrast, forest cover, herbaceous vegetation, water bodies and shrubland declined by 30%, 4%, 20% and 20%, respectively. Similarly, Muche et al., (2023) noted an increasing trend in the proportion of cultivated land, built-up area and barren land, which make up approximately 78.9% of the northeastern highlands of Ethiopia. Similarly, the other three LULC types (forestland, grassland and water bodies) decreased during the study periods, together comprising 21.1% of the total. Furthermore, Mariye et al., (2022) reported similar findings in their study, revealing a significant decrease in forest cover and a notable increase in cultivated land over a period of approximately 45 years in south-central Ethiopia. The changes in land use and land cover (LULC) perceptions reported by the participants aligned with the outcomes observed through remote sensing analysis, which revealed a decrease in forest area and an increase in built-up area (Mariye et al., 2022).

Forest cover, water bodies and grasslands diminishing in Ethiopia is concerning reported Negese, (2021). Their study revealed a decrease in water bodies (10.34%) and natural vegetation (17.21%) for over two decades. A similar trend of diminishing natural habitats was observed in Ghana by Tuffour-mills, Antwi-agyei and Addo-fordjour, (2020) where analysis of Landsat imagery revealed forest cover loss and conversion to agriculture and settlements.

The current study revealed that the expansion of built-up areas and cultivated lands reflects population growth and agricultural demands. This aligns with Tsegaye, (2019) who studied land-use change in Ethiopia's Afar Region and attributed forest loss (2.4% per decade) to population pressure and agricultural expansion.

6.2 Perceived Drivers of Observed Changes in the Wetland

This study also reaffirmed the drivers of observed changes in the Bangweulu Wetland and the surrounding areas. The findings in the current study align with previous research conducted in the Barotse Floodplain, Zambia. Banda et al. (2023) reported a similar trend: cropland expansion occurring at the expense of forestland. This study identified climate variability, population growth, settlement establishment, urbanization, farmland expansion and fuelwood collection as the major drivers of land-use and land-cover (LULC) changes in the floodplain. This finding aligns with the findings of the current study, where factors population growth, agricultural activities, settlements and the ecosystem services decline are highlighted as the primary causes of the observed LULC changes in the Bangweulu Wetland and surrounding areas.

The current study revealed population growth as a leading driver matching with Phethi and Gumbo, (2019) who also reported that population growth was a key driver of land use change in Makhitha village, South Africa. Their research revealed that as the population grew, there was increased demand for land for food and housing, leading to more intensive agricultural practices and the expansion of cultivated areas. Similarly, Odote, (2019), in a study focusing on the Nyando Basin in Kenya, attributed the increased wetland degradation to a combination of factors, including rapid population growth and demand for agricultural land and resources. In their investigation of wetland loss on the Iranian Plateau, Ghajarnia et al. (2020) also identified population growth along with agricultural expansion and water resource management, as the principal causes.

Mainuri, (2018) conducted a study in Kenya and reported similar results, suggesting that human settlement and economic development are major factors driving land-use decisions in the middle River Njoro Watershed. Similarly, Bae et al., (2017) examined the influence of land-use changes on flood risks in South Korea and identified the conversion of wetlands to residential and commercial areas as a key factor contributing to increased flood hazards. Alikhani et al., (2021) in their study on freshwater wetlands in Finland, attributed fragmentation and habitat loss to increased settlements. These developments lead to changes

in lifestyle, consumption patterns and production methods, all of which have an impact on land use. As communities establish settlements, they require land for housing, infrastructure development and other human activities. This demand for land often leads to the conversion of natural habitats, such as wetlands, forests and agricultural areas into residential zones.

Muche et al., (2023) also reported that the expansion of settlements and cultivated land into natural ecosystems, such as forests, water bodies and grasslands, has led to a significant decline in ecosystem services (ESs) in the northeastern highlands of Ethiopia. Similarly, Assefa et al., (2021) in their study on the impacts of land-use and land-cover changes on wetland ecosystem service values in peri-urban and urban area of Bahir Dar city in northwestern Ethiopia, observed that the unique ecological characteristics of wetland ecosystems, including their diverse biodiversity, water resources and hydrological functions, make wetlands valuable hence attracting human activities, which in turn influences land use patterns. Zorrilla-Miras et al., (2014) in their study of the Iberian Peninsula identified various drivers of LULC changes in wetlands, including water diversion, pollution and agricultural intensification. They highlighted how these changes negatively impact ecosystem services such as water purification, carbon sequestration and biodiversity. This aligns with the observation in this study, where a decrease in ecosystem services emerged as one of the drivers of LULC change in the Bangweulu Wetland.

The current study further revealed that expansion of farming and livestock grazing has significantly impacted land cover and land use within the Bangweulu Wetland, Similar findings have been reported by the United Nations Convention to Combat Desertification (UNCCD, (2017) Global Land Outlook, which highlighted that modern crop and livestock management practices often result in soil erosion, declining biodiversity, and reduced water filtration and availability. Chilufya, (2011) in his study on sustainable agriculture practices as a remedy for the negative effects of climate change on food security in Zambia, emphasized the need for sustainable agricultural practices, such as agroforestry, conservation agriculture and appropriate land management techniques, to mitigate the negative environmental impacts of agriculture while ensuring food security and preserving the ecological integrity of wetlands. William and Turner II, (2014) explored LULC changes in China and showed how agricultural expansion was a major driver of deforestation and the conversion of natural lands to farmland, including wetlands.

Handavu et al., (2019) reported that forest decline was a driver of LULC change with 79% of the participants in the Miombo woodlands of the Copperbelt Province in Zambia, indicated that they had cleared forestland within the past decade. The primary reasons cited for this deforestation were also related to the desire to increase agricultural production. Similarly, Ardiansah, Rijal and Barkey (2021), in the Bonehau Watershed, also revealed that the decline in forest was greatest in primary forests. This is consistent with the observations made in this study, which showed that forests serve as a reliable source of income for many people and that charcoal burning is a common practice among households, resulting in forest cover loss.

6.3 Factors that Influence the Perceived Causes of LULC change

The socioeconomic determinants of perceived drivers revealed in this current study agrees with research conducted by Handavu et al. (2019) and Munthali et al. (2019), who showed that migration was a significant determinant affecting household land use patterns and population growth in the Miombo woodlands of the Copperbelt Province in Zambia and Dedza District, Central Malawi Region. Ghosh et al. (2015), in their study on the Sundarbans mangrove forest in India and Bangladesh, emphasized the role of migration and population pressure in contributing to the degradation of this complex wetland ecosystem. They highlighted the need to address underlying socioeconomic issues alongside conservation efforts.

The combination of people moving to the area and a high number of births within the existing population helps explain the increasing population size in the Bangweulu Wetland and surrounding areas. The findings observed in this study align with the findings of Munthali et al., (2019) in Malawi, who attributed this phenomenon to high fertility rates, early marriages, high birth rates, declining mortality rates, polygamy, immigration and illiteracy. Similarly, Ebanyat et al., (2010), in Eastern Uganda, identified several factors that influence land use decisions, including market demand for agricultural products, soil quality, household education level, farming experience and proximity to markets. These socioeconomic factors drive farmers to increase agricultural activities, leading to land use changes as natural habitats are converted for agricultural purposes.

Similarly, Meijerink and Roza, (1971) and Musumali et al., (2009) stated that the distribution of economic activities as presented above demonstrates the dominant role of farming, fishing and business in driving local economies in rural and urban poverty in Africa, Latin America, East Asia and Zambia respectively. The Food Crop and Seed Project documented by Manintveld, Mulila-Mitti and Almekinders, (2004) in Zambia reported on a similar range of

initiatives focusing on crop improvement, conservation farming, natural resource management, social development, the generation of economic opportunities and the development of effective marketing strategies that have helped improve the agricultural industry. The socioeconomic factors also shed light on the relationship between energy sources and land use dynamics, with Chidumayo and Savanna, (2018) finding similar results on a study on tropical ecosystems around the world, which reported a significant link between wood fuel use and deforestation.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

This chapter presents the conclusions and recommendations of the study.

7.1 Conclusion

Analysis of remote sensing data revealed a significant decrease in forest coverage and a considerable increase in cropland within the study area over the past 30 yrs. The observed changes in land use align with the findings obtained through remote sensing image analysis. This study identified five LULC categories, in which notable changes occurred between 1990, 2000, 2010 and 2020. Forestland decreased from 45,298.93 km² in 1990 to 33,233.52 km² in 2020, with an estimated total forest loss of 12,065.42 km² during this period. Similarly, grasslands decreased from 32,557.91 km² in 1990 to 26,418.19 km² in 2020. Conversely, the area of settled land expanded from 356.69 km² to 2,210.38 km² during the study period. The findings from the imageries indicate that croplands have become the dominant LUC type, increasing from 165.27 km² in 1990 to 5,108.13 km² in 2020. Throughout the study period, there was a consistent trend of increasing cropland and settlement areas at the expense of other land use categories. This highlights the need for effective conservation measures by governmental and nongovernmental organizations in the study area.

This study also examined the drivers of land use and land cover change in the Bangweulu Wetland and its surrounding areas. Population growth was identified as a significant driver, with a high average score of 3.76 out of 5. The establishment and expansion of human settlements had an average score of 3.66 out of 5, while the decline of ecosystem services had a mean score of 3.57 out of 5. This is because the unique ecological characteristics of the wetland make it an attractive resource for human activities, contributing to land use changes resulting in the loss of natural vegetation and changes in hydrological patterns. The decline in forest cover, which was driven by factors such as logging and agricultural expansion had a mean score of 2.64 out of 5.

Minor drivers such as the built environment, recreation and industry had comparatively lower mean scores of 2.21, 1.54 and 1.34 respectively, suggesting a lesser impact on land use changes in the Bangweulu Wetland and surrounding areas. The results of the logistic regression analysis on perceptions of land use and land cover change indicated that the length of time an individual lived in the residence yielded a p-value of 0.000 concerning their views on population increase and agricultural expansion as drivers of land use and land cover (LULC) change. This suggests that there were more individuals who had been in the area for a longer duration.

This is likely because to view population growth and agricultural development are noteworthy factors influencing LULC change. Additionally, farming had a p-value of 0.038, indicating that individuals whose main economic activity was farming were likely to recognize the significant effects of LULC change and its drivers in the community.

The socioeconomic determinants of land use change in the Bangweulu Wetland and its surrounding areas are interconnected, and the results revealed that agricultural development and market demands have led to increased farming activities in the region, with cash crops such as rice, cassava, groundnuts and maize becoming the dominant economic activity. Nongovernmental organization (NGO) projects have played a significant role in promoting agricultural development in Luapula Province, enhancing farmers' capabilities and increasing their engagement in farming activities.

Energy sources and charcoal burning, primarily for cooking purposes, have contributed to the decline in forest cover and have far-reaching environmental consequences for wetland ecosystems and associated forest resources, with 51% of the participants saying that they use charcoal and wood for cooking purposes. These socioeconomic determinants highlight the relationships among human activities, economic considerations and environmental changes in shaping land use patterns in the Bangweulu Wetland and its surroundings. Comprehensive consideration of these factors is essential when addressing land use planning and conservation efforts to ensure sustainable development and the preservation of valuable natural resources.

The demands of agricultural development programmes, energy sources and markets collaboratively determine the difficult variety of land use in a region, ultimately contributing to its current transformation. If this trend continues, it will have significant environmental and economic consequences, negatively impacting local livelihoods.

To ensure sustainable rural livelihoods, it is crucial to implement appropriate land resource management policies and population strategies based on community-level considerations to mitigate the rapid rates of LUC conversion.

7.2 Recommendations

Based on the findings of this study, the following recommendations are made for both public and nongovernmental agencies and researchers.

7.2.1. Community Sensitization to Proper Fertilizer Usage

The community has to be sensitized on how fertilizer usage is crucial for sustainable agriculture, as it educates farmers about the benefits of judicious fertilizer use, such as increased crop yields and improved soil fertility. It is also important to convey the drawbacks of overusing or misusing fertilizers, such as soil degradation, water pollution and health hazards. Comprehensive community sensitization programmes can be designed by the Government and other academic researchers, focusing on the correct application of fertilizers and promoting organic and natural alternatives to synthetic fertilizers.

7.2.2. More Detailed Studies on Human-Environment Relations for Sustainability

More in-depth studies by the Government, NGOs and academic researchers on human-environment relations must to be carried out to achieve long-term sustainability, especially in catchment areas. These studies should consider social, economic and ecological dimensions, and assess the impact of agriculture on ecosystems, water quality and biodiversity.

7.2.3. Usage of Sustainable Agricultural Practices

Sustainable agricultural practices, such as crop rotation, organic farming, agroforestry and integrated pest management should be encouraged because they are crucial for environmental preservation and long-term food security. Governments, NGOs and agricultural officials can play a crucial role in providing education and resources to encourage these shifts. In summary, by promoting community sensitization to proper fertilizer usage, conducting more detailed studies on human-environment relations and advocating for sustainable agricultural practices, we can pave the way for more sustainable and harmonious coexistence with our environment. These efforts not only enhance agricultural productivity but also safeguard our natural resources and the well-being of our communities, contributing to a brighter and more sustainable future for all.

REFERENCES

- Acreman Mike and Bullock Andy. (2003) The role of wetlands in the hydrological cycle, *Hydrology and Earth system sciences*, 7(3), pp. 358–389. Available at: <https://hess.copernicus.org/articles/7/358/2003/hess-7-358-2003.html>
- African Parks. (2008) The Story of Bangweulu, African parks, pp. 1–2. Available at: <https://www.africanparks.org/sites/default/files/uploads/resources/2018-10/Bangweulu%20Factsheet.pdf>
- Alam Akhtar, S.M. Rashid, M. Sultan Bhat and Ashaq Hussain Sheikh. (2011) Impact of land use/land cover dynamics on himalayan wetland ecosystem, *Journal of Experimental Sciences*, 2(3), pp. 60–64. Available at: <https://updatepublishing.com/journal/index.php/jes/article/view/1819>.
- Ardiansah Tri, Rijal Syamsu and Barkey A. Roland. (2021) Land use change projection in Bonehau Watershed 2031, *IOP Conference series: Earth and environmental science*, 870(1). Available at: <https://doi.org/10.1088/1755-1315/870/1/012028>.
- Assefa Workiyie Worie, Eneyew Belachew Getnet and Wondie Ayalew. (2021) The impacts of land-use and land-cover change on wetland ecosystem service values in peri-urban and urban area of Bahir Dar City, Upper Blue Nile Basin, Northwestern Ethiopia, *Ecological processes*, 10(1), pp. 1–18. Available at: <https://doi.org/10.1186/s13717-021-00310-8>.
- Artuso Filippo and Guijt Irene. (2020) Global Megatrends: Mapping the forces that affect us all, *OXFAM Papers*, pp. 1–12. Available at: <https://oxfamilibrary.openrepository.com/bitstream/handle/10546/620942/dp-global-megatrends-mapping-forces-affect-us-all-310120-en.pdf?sequence=1&isAllowed=y>.
- Banda Arnold Mahonko, Kawawa Banda, Enock Sakala, Machaya Chomba, Nyambe Anayawa Imasiku. (2023) Assessment of land use change in the wetland of Barotse Floodplain, Zambezi River Sub-Basin, Zambia, *Natural hazards*, 115(2), pp. 1–19. Available at: <https://doi.org/10.1007/s11069-022-05589-0>.
- Bewick Viv, Cheek Liz and Ball Jonathan. (2005) Statistics review 14: Logistic regression, *Critical Care*, 9(1), pp. 1–7. Available at: <https://doi.org/10.1186/cc3045>.
- Briassoulis Helen. (2000) Factors influencing land-use and land-cover change, *Land use, land cover and soil sciences*, I, pp. 1–7. Available at: <https://www.eolss.net/sample-chapters/c12/e1-05-01-03.pdf>.

- Cai Wenming, Xue Liu, Dapeng Zhang and Farzana Akter. (2022) Impact of land cover changes on the wetland ecosystem water environment using soft computing methods, *Mathematical problems in engineering*, 2022, pp. 1–9. Available at: <https://doi.org/10.1155/2022/3673758>.
- Central Statistical Office. (1990) Copperbelt province analytical report Vol 2.pdf, pp. 1–188. Available at: <https://catalog.ihsn.org/catalog/5558/related-materials>.
- Central Statistical Office. (2022) Census of Population and Housing. pp. 1–39. Available at: <https://www.cso.ie/en/releasesandpublications/ep/p-cpr/censusofpopulation2022-preliminaryresults/introduction/>.
- Chakrapani Chuck. (2023) Statistical note, Aid for trade at a glance 2022, pp. 123–124. Available at: <https://doi.org/10.30875/9789287073822-062.zhtml>.
- Changwe Kalutwa Kabamba. (2020) Assessing wetland degradation using land use and land cover change in Lukanga Wetland , Zambia, *Research.Mu.Ac.Zm*, 1(1), pp. 1–12. Available at: <https://research.mu.ac.zm/research/index.php/mu/article/view/42>.
- Chen Thomas T., LeGal Yves and Miyachi Shigetoh. (1999) Marine biotechnology, *Marine biotechnology*. Available at: <https://doi.org/10.1007/bf03391712>.
- Chidumayo Emmanuel and Savanna Makeni. (2018) The environmental impacts of charcoal production in tropical ecosystems of the world : A synthesis, (April 2013). Available at: <https://doi.org/10.1016/j.esd.2012.07.004>.
- Chidumayo Emmanuel. (1987) A shifting cultivation land use system under population pressure in Zambia, *Agroforestry systems*, 5(1), pp. 15–25. Available at: <https://doi.org/10.1007/BF00046411>.
- Chilufya Gregory Chanda. (2011) Can Sustainable Agriculture Practices Remedy the Negative Effects of Climate Change on Food Security in Zambia?, (June). pp. 1–55. Available at: <https://repository.jctr.org.zm/handle/123456789/125>.
- CIAT and World Bank. (2017) Climate-smart agriculture in Zambia., *Climate-smart agriculture country profile series*, pp. 1–25. Available at: <https://ccafs.cgiar.org/publications/climate-smart-agriculture-zambia#.WwG9JUgvw2w>.
- Courouble Marianne, Nick Davidson, Lars Dinesen, Siobhan Fennessy, Thomas Galewski, Anis Guelmami, Ritesh Kumar, Rob McInnes, Christian Perennou, Lisa-Maria Rebelo, Hugh Robertson, Lorena Segura-Champagnon, Matthew Simpson, David Stroud and Nigel Dudley

- Design. (2021) Global wetland outlook: Special edition 2021, pp. 1–56. Available at: <https://www.global-wetland-outlook.ramsar.org/>.
- Davidson Nick C. (2014) How much wetland has the world lost? Long-term and recent trends in global wetland area, *Marine and freshwater research*, 65(10), pp. 1–9. Available at: <https://doi.org/10.1071/MF14173>.
- Dixon M.J.R., J. Loh, N.C. Davidson, C. Beltrame, R. Freeman and M. Walpole. (2016) Tracking global change in ecosystem area: The wetland extent trends index, *Biological conservation*, 193, pp. 27–35. Available at: <https://doi.org/10.1016/j.biocon.2015.10.023>.
- Doering Otto and Sorensen Ann. (2018) The land that shapes and sustains us, *How to feed the World*, pp. 46–58. Available at: <https://doi.org/10.5822/978-1-61091-885-5>.
- Ebanyat Peter, Nico De Ridder, Andre De Jager, Robert J. Delve, Mateete A. Bekunda and Ken E. Giller (2010) Drivers of land use change and household determinants of sustainability in smallholder farming systems of Eastern Uganda, *Population and environment*, 31(6), pp. 474–506. Available at: <https://doi.org/10.1007/s11111-010-0104-2>.
- Ellis Erle C. (2021) Land use and ecological change: A 12,000-year history, *Annual review of environment and resources*, pp. 1–33. Available at: <https://doi.org/10.1146/annurev-environ-012220-010822>.
- Endfield Georgina H. (2009) *Environmental history, A companion to environmental geography*, pp. 1–36. Available at: <https://doi.org/10.1002/9781444305722.ch14>.
- Eshleman Keith. (2004) Hydrological consequences of land use change: A review of the state-of-science, Washington DC American geophysical union geophysical monograph Series, 153, pp. 13–29. Available at: <https://doi.org/10.1029/153GM03>.
- Finlayson Max, Davidson Nick, Fennessy Siobhan, Coates David, Gardner Royal C, Darwall Will, Dema Michael, Everard Mark, McRae Louise, Perennou Christian, Stroud David, Bambaradeniya Channa, Davies Peter, Fang Wei-Ta, Hilomen Vincent, Kulindwa Kassim, Martinez Laura, Ricaurte Luisa, Scoullos Michael, De Silva Sanjiv, Michael Steiner Gert, Lead Baker Chris, Kumar Ritesh, Stroud David, Barchiesi Stefano, Okuno Erin, Perennou Christian and Dudley, Nigel. (2018) Global wetland outlook; State of the world’s wetlands and their services to people 2018, (October), pp. 1–89. Available at: https://www.researchgate.net/publication/328093181_Global_Wetland_Outlook_State_of_th

e_World%27s_Wetlands_and_Their_Services_to_People?enrichId=rgreq-d0518c6f65119e4c3c17ed7d6622e392-XXX&enrichSource=Y292ZXJQYWdlOzMyODA5MzE4MTtBUzo2NzgyNjI4MTY2NjE1MDRAMTU.

Foley A. Jonathan, Ruth DeFries, Gregory P. Asner, Carol Barford, Gordon Bonan, Stephen R. Carpenter, mF. Stuart Chapin, Michael T. Coe, Gretchen C. Daily, Holly K. Gibbs, Joseph H. Helkowski, Tracey Holloway, Erica A. Howard, Christopher J. Kucharik, Chad Monfreda, Jonathan A. Patz, Colin Prentice, Navin Ramankutty and Peter K. Snyder. (2005) Global consequences of land use, *Science*, 309(5734), pp. 1–7. Available at: <https://doi.org/10.1126/science.1111772>.

Fonte C.C., L. See, J. C. Laso-Bayas, M. Lesiv and S. Fritz. (2020) Assessing the accuracy of land use land cover (lulc) maps using class proportions in the reference data, *ISPRS annals of the photogrammetry, Remote sensing and spatial information sciences*, 5(3), pp. 669–674. Available at: <https://doi.org/10.5194/isprs-Annals-V-3-2020-669-2020>.

Foody Giles. (2002) Status of land cover classification accuracy assessment, *Remote sensing of environment*, 80, pp. 185–201. Available at: [https://doi.org/10.1016/S0034-4257\(01\)00295-4](https://doi.org/10.1016/S0034-4257(01)00295-4).

Foody Giles. (2020) Explaining the unsuitability of the kappa coefficient in the assessment and comparison of the accuracy of thematic maps obtained by image classification, *Remote sensing of environment*, 239, pp. 111–630. Available at: <https://doi.org/10.1016/j.rse.2019.111630>.

FWA-SCARED. (2011) Framework for water security and climate resilient development (FWA-SACRED). pp. 1–52. Available at: <https://www.preventionweb.net/publication/water-security-and-climate-resilient-development-strategic-framework>.

Gantioler Sonja, Gundimeda Haripriya, Sukhdev Pavan, Tucker Graham, Martin Jock and White Stephen. (2009) The economics of ecosystems and biodiversity TEEB for national and international policy makers Part I: The need for action, *Policy*, pp. 1–429. Available at: https://www.teebweb.org/wp-content/uploads/Study_and_Reports/Reports/National_and_International_Policy_Making/TEEB_for_National_Policy_Makers_report/TEEB_for_National.pdf.

Ghajarnia Navid, Georgia Destouni, Josefin Thorslund, Zahra Kalantari, Imenne Åhlén, Jesús A. Anaya-Acevedo, Juan F. Blanco-Libreros, Sonia Borja, Sergey Chalov, Aleksandra Chalova, Kwok P. Chun, Nicola Clerici, Amanda Desormeaux, Bethany B. Garfield, Pierre Girard, Olga Gorelits, Amy Hansen, Fernando Jaramillo, Jerker Jarsjö, Adnane Labbaci, John Livsey,

Giorgos Maneas, Kathryn McCurley Pisarello, Sebastián Palomino-Ánge, Jan Pietro'n, René M. Price, Victor H. Rivera-Monroy, Jorge Salgado, A. Britta K. Sanne, Samaneh Seifollahi-Aghmiuni, Ylva Sjöberg, Pavel Terskii, Guillaume Vigouroux, Lucia Licero-Villanueva and David Zamora. (2020) Data for wetlandscapes and their changes around the world, *Earth system science data*, 12(2), pp. 1083–1100. Available at: <https://doi.org/10.5194/essd-12-1083-2020>.

Glewwe Paul and Levin Micheal. (2005) Chapter XVI presenting simple descriptive statistics from household survey data, *Applied economics*, pp. 335–354. Available at: https://www.google.com/search?q=Chapter+XVI+Presenting+simple+descriptive+statistics+from+household+survey+data&client=opera&sca_esv=567523571&sxsrf=AM9HkKkboSFb4AvmsFzefUL14-dHaVqWsg%3A1695371467806&ei=y1ANZbjMMMuP9u8P396y8Ac&ved=0ahUKEwj43ebw5r2BAxXLh_0.

Gutu Sakketa, T. (2023) Urbanisation and rural development in Sub-Saharan Africa: A review of pathways and impacts, *Research in globalization*, 6 (May), pp. 1–15. Available at: <https://doi.org/10.1016/j.resglo.2023.100133>.

Handavu Ferdinand, Chirwa Paxie W.C. and Syampungani Stephen. (2019) Socio-economic factors influencing land-use and land-cover changes in the Miombo woodlands of the Copperbelt Province in Zambia, *Forest policy and economics*, 100 (June 2017), pp. 75–94. Available at: <https://doi.org/10.1016/j.forpol.2018.10.010>.

Hannah V. Herrero, Jane Southworth, Erin Bunting And Brian Child. (2017) Using repeat photography to observe vegetation change over time in Gorongosa National Park, *African studies quarterly*, 17(2), pp. 65–82. Available at: https://asq.africa.ufl.edu/wp-content/uploads/sites/168/Herrero.HD-ed_a4.pdf.

Hijmans, Robert J., Mariana Cruz, Edwin Rojas and Luigi Guarino. (2001) DIVA-GIS, version 1.4. A geographic information system for the management and analysis of genetic resources data. Manual. International Potato Center, Lima, Peru. pp. 1–19. Available at: <https://www.bing.com/search?q=Hijmans%2C+Robert+J.%2C+Mariana+Cruz%2C+Edwin+Rojas+and+Luigi+Guarino.+2001.+DIVA-GIS%2C+version+1.4.+A+geographic+information+system+for+the+management+and+analysis+of+genetic+resources+data.+Manual.+International+Potato+Center%2C+Lima%2C+Peru.&form=ANNTH1&refig=78e09a2eb6034cf2804514976c62c72f&pc=U531>.

- Hu Shengjie, Zhenguo Niu, Yanfen Chen, Lifeng Li and Haiying Zhang. (2017) Global wetlands: Potential distribution, wetland loss, and status, *Science of the total environment*, 586, pp. 319–327. Available at: <https://doi.org/10.1016/j.scitotenv.2017.02.001>.
- Hua Xiangping, Jan Sandstad Næss, Cristina Maria Iordana, Bo Huang, Wenwu Zhao and Francesco Cherubini. (2021) Recent global land cover dynamics and implications for soil erosion and carbon losses from deforestation, *Anthropocene*, 34, pp. 1–13. Available at: <https://doi.org/10.1016/j.ancene.2021.100291>.
- Hughes, J. S. and Hughes, R.H. (1992) *IUCN_1992-Dir_African_Wetlands.pdf*. IUCN, Gland Switzerland and Cambridge, UK/ UNEP, Nairobi, Kenya/ WCMC, Cambridge, UK, pp. 1–820. Available at: <https://portals.iucn.org/library/sites/library/files/documents/1992-007.pdf>.
- Huntington I. Justin, Katherine C. Hegewisch, Britta Daudert, Charles G. Morton, John T. Abatzoglou, Daniel J. Meevov and Tyler Erickson. (2017) Climate engine: Cloud computing and visualization of climate and remote sensing data for advanced natural resource monitoring and process understanding, *Bulletin of the American meteorological society*, 98(11), pp. 2397–2409. Available at: <https://doi.org/10.1175/BAMS-D-15-00324.1>.
- Intergovernmental Panel on Climate Change. (2019) IPCC special report on climate change, desertification, land degradation, sustainable land management, food security and Greenhouse; Summary for policymakers approved draft, *Research handbook on climate change and agricultural law*, pp. 1–41. Available at: https://www.ipcc.ch/site/assets/uploads/2019/08/4.-SPM_Approved_Microsite_FINAL.pdf.
- Islam Kamrul, Jashimuddin Mohammed, Nath Biswajit and Kumar Tapan. (2018) The Egyptian journal of remote sensing and space sciences land use classification and change detection by using multi-temporal remotely sensed imagery : The case of Chunut wildlife sanctuary , *The Egyptian journal of remote sensing and space sciences*, 21(1), pp. 37–47. Available at: <https://doi.org/10.1016/j.ejrs.2016.12.005>.
- Jamal Saleha and Ahmad Wani Suhail. (2020) Assessing land use land cover dynamics of wetland ecosystems using landsat satellite data, *SN Applied sciences*, 2(11), pp. 1–24. Available at: <https://doi.org/10.1007/s42452-020-03685-z>.
- Jean-Philippe Jenny, Orlane Anneville, Fabien Arnaud, Yoann Baulaz, Damien Bouffard, Isabelle Domaizon, Serghei A. Bocaniov, Nathalie Chèvre, Maria Dittrich, Jean-Marcel Dorioz, Erin S. Dunlop, Gaël Dur, Jean Guillard, Thibault Guinaldo, Stéphan Jacquet, Aurélien Jamoneau,

Zobia Jawed, Erik Jeppesen, Gail Krantzberg, John Lenters, Barbara Leoni, Michel Meybeck, Veronica Nava, Tiina Nõges, Peeter Nõges, Martina Patelli, Victoria Pebbles, Marie-Elodie Perga, Serena Rasconi, Carl R. Ruetz III, Lars Rudstam, Nico Salmaso, Sharma Sapna, Dietmar Straile, Olga Tammeorg, Michael R. Twiss, Donald G. Uzarski, Anne-Mari Ventelä, Warwick F. Vincent, Steven W. Wilhelm, Sten-Åke Wängberg and Gesa A. Weyhenmeyer. (2020) Scientists warning to humanity: Rapid degradation of the world's large lakes, *Journal of Great Lakes research*, 46(4), pp. 686–702. Available at: <https://doi.org/10.1016/j.jglr.2020.05.006>.

Kaizen Consulting (2020) The Republic of Zambia African Development Bank Zambia Aquaculture Enterprise Development Project Kasempa Site environmental project brief in respect of the proposed fish ponds and infrastructure development in Kasempa District December 2020 prepared by K, pp. 1–153. Available at: <https://www.afdb.org/en/documents/zambia-proposed-fish-ponds-and-infrastructure-development-kasempa-district-zaedp-p-zm-aaf-002-environmental-project-brief-summary>.

Kalantary Courouche. (2010) Climate change in Zambia: Impacts and adaptation, *Global majority E-journal*, 1(2), pp. 85–96. Available at: https://www.american.edu/cas/economics/ejournal/upload/kalantary_accessible.pdf.

Kamble Santosh, Rashinkar Gajanan, Kumbhar Arjun and Salunkhe Rajashri. (2012) Hydrotrope induced synthesis of 1,8-dioxo-octahydroxanthenes in aqueous medium, *Green chemistry letters and reviews*, 5(1), pp. 101–107. Available at: <https://doi.org/10.1080/17518253.2011.584217>.

Kamweneshe Bernard Mwila. (2000) Ecology, conservation and management of the black lechwe (*Kobus leche smithemani*) in the Bangweulu Basin, Zambia, pp. 1–169. Available at: <https://repository.up.ac.za/handle/2263/30551>

Kapos Valerie, Jorn Scharlemann, Alison Campbell, Anna Chenery and Barney Dickson. (2008) Impacts of climate change on biodiversity: A review of the recent scientific literature, (October), pp. 1–56. Available at: <https://wedocs.unep.org/bitstream/handle/20.500.11822/8629/Impacts-climate-change-biodiversity.pdf>

Kolding Jeppe, Ticheler Henne and Chanda Ben. (1996) Assessment of the Bangweulu swamps fisheries, (December), pp. 1–51. Available at: https://www.academia.edu/676518/Assessment_of_the_Bangweulu_swamps_fisheries_final_report.

- Lahasing Guslia, Joimin Jane and Anton Ann. (2015) The Important of wetland in sustainable water management, Sabah wetlands conservation society, pp. 1–11. Available at: www.sabahwetlands.org.
- Landis J. Richard and Koch Gary G. (1977) An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers, *Biometrics*, 33(2), pp. 363–374. Available at: <https://doi.org/10.2307/2529786>.
- Lehner Bernard and WWF-Zambia. (2020) Technical documentation version 1.0, pp. 1–27. Available at: https://hydroatlas-zambia.weebly.com/uploads/1/2/4/0/124083140/hydroatlas_zambia_techdoc_v10.pdf.
- Li Zhaofu. (2015) Impacts on wetlands of large-scale land-use changes by agricultural development : The small Sanjiang Plain , China, (June). pp. 1–6. Available at: <https://doi.org/10.1579/0044-7447-33.6.306>.
- Liu Hongyu, Shikui Zhang, Zhaofu Li, Xianguo Lu and Qing Yang. (2004) Impacts on wetlands of large-scale land-use changes by agricultural development: The small Sanjiang Plain, China, *Ambio*, 33(6), pp. 306–310. Available at: <https://doi.org/10.1579/0044-7447-33.6.306>.
- Lorentz Simon, Sean Thornton-Dibb, Cobus Pretorius and Phakade Goba. (2004) Hydrological systems modelling research programme : hydrological processes Phase II quantification of hillslope, Riparian and Wetland Processes. pp 1–132. Available at: <https://www.wrc.org.za/wp-content/uploads/mdocs/1086-1-041.pdf>
- Luyssaert Sebastiaan, Jammet Mathilde, Stoy Paul C., Estel Stephan, Pongratz Julia, Ceschia Eric, Churkina Galina, Don Axel, Erb Karlheinz, Ferlicoq Morgan, Gielen Bert, Grünwald Thomas, Houghton Richard A., Klumpp Katja, Knohl Alexander, Kolb Thomas, Kuemmerle Tobias, Laurila Tuomas, Lohila Annalea, Loustau Denis, McGrath Matthew J., Meyfroidt Patrick, Moors Eddy J., Naudts Kim, Novick Kim, Otto Juliane, Pilegaard Kim, Pio Casimiro A., Rambal Serge, Rebmann Corinna, Ryder James, Suyker Andrew E., Varlagin Andrej Wattenbach Martin and Dolman, A. Johannes. (2014) Land management and land-cover change have impacts of similar magnitude on surface temperature, *Nature climate change*, 4(5), pp. 389–393. Available at: <https://doi.org/10.1038/nclimate2196>.
- Mainuri Zachary Gichuru. (2018) Impact of human settlement on land use/land cover changes in the Middle River Njoro Sub Watershed in Kenya, *European journal of multidisciplinary studies*, 3(4), pp.1– 180. Available at: <https://doi.org/10.26417/ejms.v3i4.p180-188>.

- Maitima Joseph, Olson JM, Mugatha SM, Mugisha S and Mutie, IT. (2010) Land use changes, impacts and options for sustaining productivity and livelihoods in the basin of lake Victoria, *Journal of sustainable development in Africa*, 12(3), pp. 189–206. Available at: https://www.researchgate.net/publication/257657203_Land_use_changes_impacts_and_options_for_sustaining_productivity_and_livelihoods_in_the_basin_of_lake_Victoria.
- Manintveld Kees, Mulila-Mitti Joyce and Almekinders Conny. (2004) Integration of biodiversity aspects in development cooperation - a case study: Food crop and Seed project in Zambia. pp.1–94. Available at: <https://cdn.sida.se/publications/files/sida3482en-food-crop-and-seed-project-in-zambia-integration-of-biodiversity-aspects-in-development-cooperation--a-case-study.pdf>
- Mariye Mehari, Jianhua Li and Maryo Melesse. (2022) Land use land cover change analysis and detection of its drivers using geospatial techniques: A case of South-central Ethiopia, *All Earth*, 34(1), pp. 309–332. Available at: <https://doi.org/10.1080/27669645.2022.2139023>.
- Mccann Kelvin. (2017) Population and distribution of wattled cranes, shoebills and other large waterbirds in the Bangweulu Swamps, Zambia, (February 2003), pp. 1–26. Available at: [https://chm.cbd.int/api/v2013/documents/768762F7-1E4D-A016-BEE2A33D4BFA98A7/attachments/207698/Bangweulu Swamps Report 2003 ShoeBills_Kamweneshe et al_2003.pdf](https://chm.cbd.int/api/v2013/documents/768762F7-1E4D-A016-BEE2A33D4BFA98A7/attachments/207698/Bangweulu%20Swamps%20Report%202003%20ShoeBills_Kamweneshe%20et%20al_2003.pdf).
- McLellan Richard, Iyengar Leena, Jeffries Barney, Oerlemans Natasja, Grooten Monique, Guerraoui May and Sunters Paul. (2014) Living planet report 2014, World Wildlife Fund, pp. 1– 180. Available at: https://d2ouvy59p0dg6k.cloudfront.net/downloads/wwf_lpr2014_low_res_for_web.pdf
- Meijerink Gerdien and Roza Pim. (1971) The role of agriculture in economic development, *The economic journal*, 81(323), pp. 580–673. Available at: <https://doi.org/10.2307/2229883>.
- Michel Gunther. (2016) Threats to wetlands, World Wildlife Fund, pp. 1–2. Available at: <https://www.epa.gov/sites/default/files/2016-02/documents/threatstowetlands.pdf>.
- Ministry of Land and Natural Resources. (2018) National policy on wetlands, food and agricultural organisation, pp. 1– 31. Available at: <https://faolex.fao.org/docs/pdf/zam189727.pdf>.
- Ministry of Tourism Environment and Natural Resources (2010) National climate change response strategy (NCCRS). Final draft. Ministry of tourism, environment and natural resources, Lusaka, (December), pp. 1–135. Available at: <https://www.adaptation->

undp.org/sites/default/files/downloads/zambia-climate_change_response_strategy.pdf.

Mosnier A, Mant R, Pirker J, Makoudjou A, Bokelo Bile D, Bodin B, Tonga P, Havlík P, Bocqueho G, Maukonen P, Obersteiner M, Kapos V, Tadoum M. (2016) Modelling land use changes in the Democratic Republic of the Congo 2000–2030, pp. 1–80. Available at: www.redd-pac.org.

Msoffe U. Fortunata, Shem C. Kifugo, Mohammed Y. Said, Moses Ole Neselle, Paul Van Gardingen, Robin S. Reid, Joseph O. Ogutu, Mario Herero and Jan de Leeuw. (2011) Drivers and impacts of land-use change in the Maasai Steppe of Northern Tanzania: An ecological, social and political analysis, *Journal of land use science*, 6(4), pp. 261–281. Available at: <https://doi.org/10.1080/1747423X.2010.511682>.

Muche Meseret, Getahun Yemata, Eyayu Molla, Wubetie Adnew and A. Muthama Muasya. (2023) Land use and land cover changes and their impact on ecosystem service values in the North-eastern Highlands of Ethiopia', *PloS one*, 18(9), pp. 1–14. Available at: <https://doi.org/10.1371/journal.pone.0289962>.

Mulilamitti Joyce, Kate Constantine and Frances Williams. (2022) An invasive species system assessment in Zambia, (March), pp. 1–22. Available at: <https://www.cabi.org/wp-content/uploads/Working-Paper-27.pdf>

Mumba Musonda. (2002) Invasive alien species in the Kafue Flats Zambia, Wetland research unit, pp. 1–9. Available at: <http://st1.asflib.net/MEDIA/ASF-CD/ASF-M-00143/stream%20outputs/Session%204b-5b%20Alien%20invasives/MMumba.pdf>

Munthali G. Maggie, Nerhene Davis, Abiodun M. Adeola, Botai O. Joel, Kamwi M. Jonathan, Chisale L. W. Harold and Orimoogunje O. I. Oluwagbenga. (2019) Local perception of drivers of land-use and land-cover change dynamics across Dedza District, Central Malawi Region, *Sustainability* (Switzerland), 11(3), pp. 1–25. Available at: <https://doi.org/10.3390/su11030832>.

Musole M. Musumali, Simon Heck, Saskia M.C. Husken and Marcus Wishart. (2009) Fisheries in Zambia: An undervalued contributor to poverty reduction, *The WorldFish Center/The world Bank. Policy Brief* 1913., pp. 1–15. Available at: http://pubs.iclarm.net/resource_centre/WF_2449.pdf<http://ideas.repec.org/b/wfi/wfbook/38677.html>.

- Nachtergaele Freddy O., Petri Monica, Biancalani Riccardo. (2016) Land degradation, World soil resources and food security. pp. 471– 498. Available at: <https://doi.org/10.4324/9781315838366-18>.
- Ncheuveu Nkwatoh Therese, Patricia Bi Asanga Fai, Martin Ngankam Tchamba and Francis Ngealekeloeh. (2021) Pesticide use practices and effects on the wetland biodiversity of Ndop, North West Region of Cameroon, International journal of environment and climate change, (July), pp. 105–116. Available at: <https://doi.org/10.9734/ijecc/2021/v11i530411>.
- Negese Ajanaw. (2021) Impacts of Land Use and Land Cover Change on Soil Erosion and Hydrological Responses in Ethiopia, 2021, pp. 15–17. Available at: https://www.researchgate.net/publication/349383181_Impacts_of_Land_Use_and_Land_Cover_Change_on_Soil_Erosion_and_Hydrological_Responses_in_Ethiopia.
- Nkolokosa C., Russell Stothard, Christopher M. Jones, Michelle Stanton, James Chirombo and Julie-Anne Akiko Tangena. (2023) Monitoring and simulating landscape changes: how do long-term changes in land use and long-term average climate affect regional biophysical conditions in Southern Malawi?, Environmental monitoring and assessment, 195(10), pp. 1247. Available at: <https://doi.org/10.1007/s10661-023-11783-9>.
- Odote Collins. (2019) The Ecosystem approach in Ocean planning and governance, Publications on Ocean development, pp. 414–442. Available at: <https://doi.org/10.1163/9789004389984>.
- Pallant Julie. (2016) SPSS survival manual, 6th edition, 2016. Open university press. pp. 1–359. Available at: [https://www.scirp.org/\(S\(czeh2tfqyw2orz553k1w0r45\)\)/reference/referencespapers.aspx?referenceid=2050871](https://www.scirp.org/(S(czeh2tfqyw2orz553k1w0r45))/reference/referencespapers.aspx?referenceid=2050871).
- Park Hyeoun Ae. (2013) An introduction to logistic regression: from basic concepts to interpretation with particular attention to nursing domain, Journal of Korean academy of nursing, 43(2), pp. 154–164. Available at: <https://doi.org/10.4040/jkan.2013.43.2.154>.
- Parveen Shaghla, Basheer Jasmineen and Praveen Bushra. (2018) A Literature review on land use land cover changes, International journal of advanced research, 6(7), pp. 1–6. Available at: <https://doi.org/10.21474/ijar01/7327>.
- Phethi .D.Mpho and Gumbo Jabulani R. (2019) Assessment of impact of land use change on the wetland in Makhitha Village, Limpopo Province, South Africa, Jamba: Journal of disaster risk

studies, 11(2), pp. 1–6. Available at: <https://doi.org/10.4102/jamba.v11i2.693>.

Phiri Darius, Jacob Mwitwa, Phillimon Ng'andwe, Kennedy Kanja, Justin Munyaka, Felix Chileshe, Patan Hamazakaza, Sydney Kapembwa & Jane Musole Kwenye (2023) Agricultural expansion into forest reserves in Zambia: A remote sensing approach, *Geocarto International*, 38(1), pp. 1–20. Available at: <https://doi.org/10.1080/10106049.2023.2213203>.

Prybutok Victor R. and Ott Lyman. (1989) An introduction to statistical methods and data analysis, *Technometrics*, 31(3), pp. 389–400. Available at: <https://doi.org/10.2307/3556159>.

Ramsar Convention Secretariat. (2002) Information sheet on Ramsar wetlands (RIS), 7(1990), pp. 1–17. Available at: <https://rsis.ramsar.org/RISapp/files/RISrep/DK2051RIS.pdf>.

Ramsar Convention Secretariat (2007) Wise use of wetlands: A conceptual framework for the wise use of wetlands. Ramsar handbooks for the wise use of wetlands, 3rd Edition, vol. 1. Ramsar Convention Secretariat, Gland, Switzerland, pp. 1–28. Available at: <https://www.ramsar.org/sites/default/files/documents/library/hbk4-01.pdf>.

Ramsar Convention Secretariat (2010) Wetlands: a global disappearing act, (3), pp. 1–2. Available at: www.ramsar.org.

Roy S. Parth, Arijit Roy, Pawan K. Joshi, Manish P. Kale, Vijay K. Srivastava, Sushil K. Srivastava, Ravi S. Dwevidi, Chitiz Joshi, Mukunda D. Behera, Prasanth Meiyappan, Yesu Sharma, Atul K. Jain, Jamuna S. Singh, Yajnaseni Palchowdhuri, Reshma. M. Ramachandran, Bhavani Pinjarla, V. Chakravarthi, Nani Babu, Mahalakshmi S. Gowsalya, Praveen Thiruvengadam, Mrinalni Kotteswaran, Vishnu Priya, Krishna Murthy V. N. Yelishetty, Sandeep Maithani, Gautam Talukdar, Indranil Mondal, Krishnan S. Rajan, Prasad S. Narendra, Sushmita Biswal, Anusheema Chakraborty, Hitendra Padalia, Manoj Chavan, Satish N. Pardeshi, Swapnil A. Chaudhari, Arur Anand, Anjana Vyas, Mruthyunjaya K. Reddy, M. Ramalingam, R. Manonmani, Pritiranjana Behera, Pulakesh Das, Poonam Tripathi, Shafique Matin, Mohammed L. Khan , Om P. Tripathi, Jyotihman Deka, Prasanna Kumar and Deepak Kushwaha. (2015) Development of decadal (1985-1995-2005) land use and land cover database for India, *Remote sensing*, 7(3), pp. 2401–2430. Available at: <https://doi.org/10.3390/rs70302401>.

Rueda Ximena and Lambin Eric F. (2014) Global agriculture and land use changes in the twenty-first century: Achieving a balance between food security, urban diets and nature conservation, *The evolving sphere of food security*, pp. 320–346. Available at: <http://www.oxfordscholarship.com/view/10.1093/acprof:oso/9780199354054.001.0001/acpro>

f-9780199354054-chapter-12.

- Ruppert Georg, Hussain Mushtaq and Müller Heimo. (2016) Accuracy assessment of satellite image classification depending on training sample, *Austrian journal of statistics*, 28(4), pp. 195–202. Available at: <https://doi.org/10.17713/ajs.v28i4.522>.
- Samuel Kayode Julius and Atobatele Remilekun Eunice. (2019) Change in administrative status, urban growth and land use/cover in a medium-sized African city, *Human geographies*, 13(1), pp. 5–22. Available at: <https://doi.org/10.5719/hgeo.2019.131.1>.
- Sarron Coralie. (2005) Effects of wetland degradation on the hydrological regime of a quaternary catchment, (September), pp. 1–56. Available at: <https://cgspace.cgiar.org/handle/10568/21623>.
- Schober Patrick and Schwarte Lothar A.. (2018) Correlation coefficients: Appropriate use and interpretation, *Anesthesia and Analgesia*, 126(5), pp. 1763–1768. Available at: <https://doi.org/10.1213/ANE.0000000000002864>.
- Secretariat of the Convention on Biological Diversity (2015) Wetlands meeting the challenges of the future, (February), pp. 1–2. Available at: <https://www.cbd.int/waters/doc/wwd2015/wwd-2015-press-brief-future-en.pdf>.
- Secretariat of the Convention on Wetlands (2022) Wetlands and agriculture: impacts of farming practices and pathways to sustainability, pp. 1–23. Available at: <http://www.fao.org/docrep/meeting/022/K8024E.pdf>.
- Sedgwick Philip and Marston Louise. (2010) Statistical question: Odds ratios', *BMJ (Online)*, 341(7769), pp. 227–229. Available at: <https://doi.org/10.1136/bmj.c4414>.
- Sellamuttu Senaratna Sonali, Sanjiv de Silva, Sophie Nguyen Khoa and Jayampathy Samarakoon (2008) Wetlands and poverty reduction project good practices and lessons learned in integrating ecosystem conservation and poverty reduction objectives in wetlands a policy brief study objectives, rationales and methodology, pp. 70–73. Available at: https://www.researchgate.net/publication/264363000_Good_Practices_and_Lessons_Learned_in_Integrating_Ecosystem_Conservation_and_Poverty_Reduction_Objectives_in_Wetlands
- Simatele Danny. (2016) Pro-poor climate change adaptation in Zambia, *Climate adaptation governance in cities and regions: Theoretical fundamentals and practical evidence*, pp. 267–284. Available at: <https://doi.org/10.1002/9781118451694.ch15>.
- Soheili Majd Maryam, Simonetto Elisabeth. and Polidori Laurent. (2012) Maximum Likelihood

Classification of high-resolution Sar images in urban areas, *The international archives of the photogrammetry, Remote sensing and spatial information sciences*, XXXVIII-4/(June), pp. 309–312. Available at: <https://doi.org/10.5194/isprsarchives-xxxviii-4-w19-309-2011>.

Sparks Adam. (2018) Nasapower: A nasa power global meteorology, surface solar energy and climatology data client for R', *Journal of open source software*, 3(30), pp. 1–3. Available at: <https://doi.org/10.21105/joss.01035>.

Steel E. Ashley, Robert M. Hughes, Aimee H. Fullerton, Stefan Schmutz, John A. Young, Michio Fukushima, Susanne Muhar, Michaela Poppe, Blake E. Feist and Clemens Trautwein. (2010) Are we meeting the challenges of landscape-scale riverine research? A review, *Living reviews in landscape research*, 4(1), pp. 1–60. Available at: <https://doi.org/10.12942/lrlr-2010-1>.

Takam Tiamgne Xavier, Kalaba Felix K. and Nyirenda Vincent R. (2021) Land use and cover change dynamics in Zambia's Solwezi copper mining district, *Scientific African*, 14, pp. 1–13. Available at: <https://doi.org/10.1016/j.sciaf.2021.e01007>.

Tanzania National Bureau of Statistics (2011) Enumerator Manual: NPS 2012 -2013, pp. 1–254. Available at: <https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=0CDUQw7AJahcKEwj4krDPhb6BAxUAAAAAHQAAAAAQAw&url=https%3A%2F%2Fmicrodata.worldbank.org%2Findex.php%2Fcatalog%2F1050%2Fdownload%2F30537&psig=AOvVaw27Ngdu1SuW1FAaJsxSNzL-&ust=1>.

The Ramsar Convention Secretariat (2007) Why conserve wetlands?, WWF India, (1), pp. 1–8. Available at: <https://www.ramsar.org/sites/default/files/documents/library/info2007-01-e.pdf>.

Tsegaye Gebrie. (2019) Land use land cover change analysis using Geospatial tools in case of Asayita Land Use Land Cover Change Analysis using Geospatial Tools in Case of Asayita District , Zone one , Afar Region , Ethiopia, *Journal of Resources Development and Management*, 29(July), pp. 1–7. Available at: https://www.researchgate.net/publication/334575950_Land_use_land_cover_change_analysis_using_Geospatial_tools_in_case_of_Asayita_district_zone_one_Afar_region_Ethiopia/link/5d35a97a92851cd0467b9aa2/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19.

Tuffour-mills Derrick., Antwi-agyei Philip. and Addo-fordjour Patrick. (2020) Trees , Forests and People Trends and drivers of land cover changes in a tropical urban forest in Ghana, *Trees*,

- Forests and People, 2(June), pp. 1–7. Available at: <https://doi.org/10.1016/j.tfp.2020.100040>.
- UNCCD (2017) Global land outlook (1st Edition), Part 1, Chapter 3, pp. 40–50. Available at: https://www.unccd.int/sites/default/files/documents/2017-09/GLO_Full_Report_low_res.pdf
- Ward Delphi, Jessica Melbourne-Thomas, Gretta T. Pecl, Karen Evans, Madeline Green, Phillipa C. McCormack, Camilla Novaglio, Rowan Trebilco, Narissa Bax, Madeleine J. Brasier, Emma L. Cavan, Graham Edgar, Heather L. Hunt, Jan Jansen, Russ Jones, Mary-Anne Lea, Reuben Makomere, Chris Mull, Jayson M. Semmens, Janette Shaw, Dugald Tinch, Tatiana J. van Steveninck, Cayne Layton. (2022) Safeguarding marine life: conservation of biodiversity and ecosystems, *Reviews in fish biology and fisheries*. Springer international publishing. pp. 65–100. Available at: <https://doi.org/10.1007/s11160-022-09700-3>.
- Wetlands International Secretariat (2014) Wetlands: why should I care ?, Ramsar Fact Sheet, pp. 1–8. Available at: http://www.ramsar.org/sites/default/files/documents/library/factsheet1_why_should_i_care_0.pdf.
- Winkler Karina, Fuchs Richard, Rounsevell Mark and Herold Martin. (2021) Global land use changes are four times greater than previously estimated, *Nature communications*, 12(1), pp. 1–10. Available at: <https://doi.org/10.1038/s41467-021-22702-2>.
- Zorrilla-Mirasa, P., I. Palomoa, E. Gómez-Baggethunc, B. Martín-López, P.L. Lomasc, C. Montes. (2014) Author 's personal copy landscape and urban planning effects of land-use change on wetland ecosystem services: marshes (SW Spain), pp. 161–174. Available at: https://www.researchgate.net/publication/258121322_Effects_of_land-use_change_on_wetland_ecosystem_services_A_case_study_in_the_Donana_marshes_SW_Spain.

APPENDICES

Appendix 1: Historical Rainfall trends of Bangweulu Wetland and surrounding areas, Zambia.

District	Female	Male	Total (2010)	Female	Male	Total (2022)	Female	Male	Average rate (2010-2022)
Serenje	58,319	59,561	117,880	79,075	79,117	158,192	2.6	2.4	2.5
Chembe	11,463	11,931	23,394	26,153	25,379	51,532	7.1	6.5	6.8
Chifunabuli	40,856	42,481	83,337	56,856	59,470	116,326	2.8	3	2.8
Mansa	100,873	104,125	204,998	160,174	166,889	327,063	3.9	4	4
Mwense	42,503	44,773	87,276	59,770	62,835	122,605	2.9	2.9	2.9
Samfya	44,841	46,728	91,569	71,267	75,922	147,189	3.9	4.1	4.1
Chitambo	24810	24,051	48,861	51,210	49,393	100,603	6.2	6.2	6.2
Chilubi	39,792	41,456	81,248	55,617	58,394	114,011	2.8	2.9	2.9

Appendix 2: Household questionnaire conducted in Bangweulu Wetland and surrounding areas, Zambia.

Investigator: Chisanga Lyoba

Questionnaire No:

Date of Interview: District:

District	Code
Serenje	1
Samfya	2
Chilubi	3
Chifunabuli	4
Chembe	5
Mwense	6
Mansa	7
Chitambo	8

1. Identification

Instructions: please put a tick in the box next to the answer of your choice

(a) Age of respondent

Age	Code
Under 18	0
18-25	1
25-45	2
45 or more	3

(b) Sex of respondent

	Code
Male	1
Female	0

(c) Marital status

	Code
Married	1
Single	2

(d) What is the highest level of your education?

	No formal education	Primary	Secondary	Tertiary
Code	0	1	2	3

2. Occupation

What is your occupation? (choose only one that applies)

	Code
Farmer	0
Business	1
Craft work	2
Construction	3
Fisherman	4
Formal Employment	5
Domestic work	6

3. Demography

(a) What is the size of your household?

Size	Code
≤2	1
2 – 5	2
>5	3

(b) How long have you lived in this Community?

	Code
<5 years	1
5-25 years	2
25-45 years	3
Born Here	4

(c) What was the reason for migration?

	Code
Marriage	0
Farming	1
Employment	2
Fishing	3
Just for change of place	4
Born here	5

4. What is your household's main sources of income?

Source	Code
Farming (crop and animals)	0
Full-time private/government Employment	1
Selling of forest produce (e.g. charcoal, firewood, timber, poles)	2
Occasional jobs	3
Self-employed (business, trade, handicraft)	4
Fishing	5

Land-use and land-cover changes

5. Have you observed any land use change in the wetland?

	Code
No	0
Yes	1

Population vs. land-use and land-cover changes

6 (a). Do you think the population of your community has increased over the past 25 years?

	Code
No	0
Yes	1
No idea	2

(b) What do you think have caused the population increase?

	Code
High birth rate	0
Human migration	1
No idea	2
No increase	3

Activities vs. land-use and land-cover changes

7. (a) what are the major economic activities done in your community

(i) Charcoal Burning (Yes 1, No 2)

(ii) Farming (Yes 1, No 2)

(iii) Fishing (Yes 1, No 2)

(iv) Business (Yes 1, No 2)

(v) Keeping livestock (Yes 1, No 2)

(b) Have these activities declined or increased over the past 25 years in your community?

	Code
Declined	0
Increased	1
Stayed the same	2
No idea	3

8. What do you think are the causes of land-use and land-cover changes in your area (**rank on a scale of 1 to 5**; 1= least contribution and 5 = extreme contribution).

RANK

CAUSE	1	2	3	4	5
Population growth					
Built environment					
Agriculture activities					
Industry					
Forest decline					
Recreation					
Settlements					
Ecosystem services decline					

	Code
Least contribution	1
Minimum contribution	2
Average contribution	3
Maximum contribution	4
Extreme contribution	5

Appendix 3: Key informant interviews in Bangweulu Wetland and surrounding areas, Zambia.

1. Tell me about your involvement in the community?
 - What types of activities have you been involved in?
2. From your knowledge and experience in the community, what are some of the land use changes you've noticed in wetland?
 - What do you think have been the reason for these changes?
 - What do you think have been the greatest challenges with the coming up of these changes?
 - Why do you feel that way?

- What suggestions do you have in terms of how we might meet these challenges?
- What do you think are the keys to reducing the effects of land use on the Wetland?
- Why do you feel that way?

3. Do you have any thoughts or ideas on activities that you think would be particularly affect the wetland?

4. Is there anyone else in the community that I should speak with about this issue, who may have some ideas land use changes in the Bangweulu wetland

5. Do you have any corporate contacts that could help us find out more on the land use changes on the wetland?

Appendix 4: Estimates of LULC area from 1990 to 2020 in Bangweulu Wetland and surrounding areas, Zambia.

	1990	2000	2010	2020
Water	2410.72	2377.55	2278.48	2278.31
Forest	45298.9	43971.70	39147.70	33233.50
Grass land	32557.90	30645.50	28710	26418.20
Settlement	356.69	446.84	841.712	2210.38
Crop land	165.27	1184.87	2714.14	5108.13

Appendix 5: Ethical Approvals from Relevant Ethics Boards



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APPROVAL OF STUDY

IORG No. 0005376

NASREC IRB No. 00006465

19th September, 2022

REF NO. NASREC-2019-JUL-016

Chisanga Lyoba

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LUSAKA

Dear Ms. Chisanga Lyoba,

RE: “LAND-USE CHANGES AND ITS DRIVERS IN THE BANGWEULU WETLAND”

Reference is made to your submission of the protocol captioned above. The NASREC resolved to approve this study and your participation as Principal Investigator for a period of one year.

REVIEW TYPE	ORDINARY REVIEW	APPROVAL NO. NASREC-2022-JUL-016
Approval and Expiry Date	Approval Date: 19 th September, 2023	Expiry Date: 18 th September, 2023
Protocol Version and Date	Version - Nil.	18 th September, 2023
Information Sheet, Consent Forms and Dates	<input type="checkbox"/> English.	To be provided
Consent form ID and Date	Version - Nil	To be provided
Recruitment Materials	Nil	Nil
Other Study Documents	Questionnaire.	
Number of Participants Approved for Study		

Specific conditions will apply to this approval. As Principal Investigator it is your responsibility to ensure that the contents of this letter are adhered to. If these are not adhered to, the approval may be suspended. Should the study be suspended, study sponsors and other regulatory authorities will be informed.

CONDITIONS OF APPROVAL

- No participant may be involved in any study procedure prior to the study approval or after the expiration date.
- All unanticipated or Serious Adverse Events (SAEs) must be reported to NASREC within 5 days.
- All protocol modifications must be approved by NASREC prior to implementation unless they are intended to reduce risk (but must still be reported for approval). Modifications will include any change of investigator/s or site address.
- All protocol deviations must be reported to NASREC within 5 working days.
- All recruitment materials must be approved by NASREC prior to being used.
- Principal investigators are responsible for initiating Continuing Review proceedings. HSSREC will only approve a study for a period of 12 months.
- It is the responsibility of the PI to renew his/her ethics approval through a renewal application to NASREC.
- Where the PI desires to extend the study after expiry of the study period, documents for study extension must be received by NASREC at least 30 days before the expiry date. This is for the purpose of facilitating the review process. Documents received within 30 days after expiry will be labelled “late submissions” and will incur a penalty fee of K500.00. No study shall be renewed whose documents are submitted for renewal 30 days after expiry of the certificate.
- Every 6 (six) months a progress report form supplied by The University of Zambia Natural and Applied Sciences Research Ethics Committee as an IRB must be filled in and submitted to us. There is a penalty of K500.00 for failure to submit the report.
- When closing a project, the PI is responsible for notifying, in writing or using the Research Ethics and Management Online (REMO), both NASREC and the National Health Research Authority (NHRA) when ethics certification is no longer required for a project.
- In order to close an approved study, a Closing Report must be submitted in writing or through the REMO system. A Closing Report should be filed when data collection has ended and the study team will no longer be using human participants or animals or secondary data or have any direct or indirect contact with the research participants or animals for the study.

- Filing a closing report (rather than just letting your approval lapse) is important as it assists NASREC in efficiently tracking and reporting on projects. Note that some funding agencies and sponsors require a notice of closure from the IRB which had approved the study and can only be generated after the Closing Report has been filed.
- A reprint of this letter shall be done at a fee.
- All protocol modifications must be approved by NASREC by way of an application for an amendment prior to implementation unless they are intended to reduce risk (but must still be reported for approval). Modifications will include any change of investigator/s or site address or methodology and methods. Many modifications entail minimal risk adjustments to a protocol and/or consent form and can be made on an Expedited basis (via the IRB Chair). Some examples are: format changes, correcting spelling errors, adding key personnel, minor changes to questionnaires, recruiting and changes, and so forth. Other, more substantive changes, especially those that may alter the risk-benefit ratio, may require Full Board review. In all cases, except where noted above regarding subject safety, any changes to any protocol document or procedure must first be approved by NASREC before they can be implemented.

Should you have any questions regarding anything indicated in this letter, please do not hesitate to get in touch with us at the above indicated address.

On behalf of NASREC, we would like to wish you all the success as you carry out your study.

Yours faithfully,



Dr. E. M. Mwanaumo

DR. E. M. MWANAUMO

**CHAIRPERSON THE UNIVERSITY OF ZAMBIA NATURAL AND APPLIED
SCIENCES RESEARCH ETHICS COMMITTEE - IRB**

cc: Director, Directorate of Research
and Graduate Studies

Assistant Director (Research), Directorate of Research and Graduate Studies
Assistant Registrar (Research), Directorate of Research and Graduate Studies