SOCIAL VULNERABILITIES AND ADAPTATION OPTIONS TO CLIMATIC HAZARDS AFFECTING RURAL WATER SUPPLY IN BAROTSE FLOODPLAIN CATCHMENT

by

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A dissertation submitted to the University of Zambia in partial fulfilment of the requirements for the degree of Master of Science in Environmental and Natural Resources Management.

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DECLARATION

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CERTIFICATE OF APPROVAL

Everjoy Mhereyenyoka's dissertation has been approved as partial fulfilment of the requirements for the award of Master of Science Degree in Environmental and Natural Resources Management by the University of Zambia.

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ABSTRACT

Climate change is altering hydrological patterns, leading to extreme weather events such as prolonged droughts, intense floods, and shifts in precipitation patterns threatening water supply systems in the Barotse Floodplain. This has adversely affected the rural communities in the Barotse floodplain as water supply systems are crucial for their livelihoods and well-being. Therefore, this study sought to investigate the susceptibility of rural communities in the Barotse Floodplains to climatic hazards affecting their water supply and identify adaptation options for ensuring sustainable water supply in the face of climate change. The study adopted a mixed method approach with a convergent parallel mixed method research design and a sample size of 205 households and 6 key informants. To collect the data a household survey was conducted in Malengwa, Lealui and Nakanya villages in Mongu District using a semi-structured interview. The quantitative data was used to assess the social vulnerability of the rural communities using the social vulnerability index. Qualitative data was analyzed thematically. The findings of the study show that Nakanya village is the most vulnerable, having an SVI score of 0.52 followed by Lealui village with an SVI score of 0.45 and finally Malengwa village with an SVI score of 0.39. Economic factors largely influenced the social vulnerability in all the three villages as they had the highest values. The findings also show that effects of climate change being experienced include an increase in the frequency of drought, increase in temperatures and lack of rainfall, floods, and heavy winds. The effects of climate change are negatively affecting the rural water supply of the Barotse floodplains in various ways with increase in frequency and severity of drought making water scarcer escalating water insecurity issues. This has led to adverse effects such as loss of crops, loss of livestock, drinking contaminated water, water shortages, hunger and starvation, diseases, reduced fishing activities and human wildlife conflict. The study found that rural communities were adapting to climate change impacts through measures such as digging and deepening wells, traveling longer distances to fetch water, limiting water usage, borehole drilling and construction of water supply mini schemes. The study identified adaptation options that can help enhance the local communities' resilience against climate change impacts on water supply. These include drilling of boreholes, introduction of irrigation schemes, household clustering, recharge mapping and riverbank infiltration. The findings of the study reveal that development of climate change resilient water infrastructure is critical in enhancing the rural communities' resilience against the impacts of climate change on water supply systems.

Keywords: *Barotse floodplains, Climate change, Rural water supply, Adaptation, Social vulnerability*

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ACRONYMS

IDP	Integrated Development Plan
IPCC	Intergovernmental Panel on Climate Change
SADC	Southern African Development Community
SVI	Social Vulnerability Index

CHAPTER ONE

INTRODUCTION

1.0 Background

Water availability at a sustainable quality and quantity is being threatened by several factors with climate change playing a leading role (Kumar, 2016). According to Rankoana (2020), the impacts of climate change on water resources are already perceived. Climate change affects the hydrologic cycle by influencing precipitation, evapotranspiration, and soil moisture with increasing temperatures (Kumar, 2016). The African continent is considered the most vulnerable because of its high exposure and low adaptive capacity (Niang *et al*., 2014). Vulnerability is the degree to which a system is susceptible to or unable to cope with the adverse effects of climate change including climate variability and extremes (Tesso *et al*., 2012). Most parts of the African continent are classified as arid and semi-arid with high drought risks (Rankoana, 2020). Niang *et al*., (2014) state that many studies in Africa point to a future decrease in water abundance due to a range of drivers and stresses that include climate change.

The African continent is warming up at a rate that is greater than the rest of the globe with drier subtropical regions warming more than the moist tropics (Niang *et al*., 2014; Rankoana, 2020). This increase in temperature has resulted in increased water stress with droughts and floods becoming more severe and more frequent (Nkhonjera and Dinka, 2017). Zambia is an example of a country where climate change impacts on water resources are already being experienced. A study by Hamududu and Ngoma, (2020) found that rainfall which is the major source of water resources in the country has been experiencing variability with droughts and floods becoming more frequent and more severe as a result of climate change. This is threatening water availability as well as distribution in the country.

The impacts of climate change on water resources directly affect other sectors of the economy through impacts on health, agriculture, industry, transport, energy supply, fisheries, forestry, tourism, mining, municipal water supply, and recreation (Ndhlovu and Woyessa, 2021; Nkhonjera and Dinka, 2017) with rural communities being more vulnerable. Rural communities are particularly vulnerable to the impacts of climate change on water resources as water resources forms a direct source of their livelihoods in the form of agriculture and domestic use (Ndhlovu and Woyessa, 2021; Nkhonjera and Dinka, 2017). In addition, rural communities do not have access to piped water. For example, in Zambia only 1.6% of the rural population have piped water with the rest of the rural residents obtaining water from sources such as hand pumps, streams, dams, and rainwater (Hamududu and Ngoma, 2020). The safety and reliability of water supplies are fundamental to the livelihood security of rural communities (Macdonald *et al*., 2009).

In Zambia, one of the water sources that is vulnerable to climate change is the Zambezi River Basin which experiences a highly variable climate (Niang *et al.*, 2014). Studies conducted in the basin predicted rising temperatures and decreasing precipitation and that season may become shorter and more variable, predicting more extended drought periods and more severe floods (Ndhlovu and Woyessa, 2021). A study by Hamududu and Ngoma, (2020) also indicated that temperature is projected to increase by 1.9 °C and 2.3 °C by 2050 and 2100, respectively, in Zambia. Rainfall is projected to decrease by about 3% by mid-century and only marginally by about 0.6% toward the end of the century across the country. This temperature rise will have a huge impact on evapotranspiration and will lead to general dryness in some areas of the basin. The annual rainfall in the basin has also been predicted to decrease which will further increase the stress on water resources. The predicted frequent and severe drought will lead to high aridity and drying up of some rivers and streams, as well as boreholes, leading to water shortages (Ndhlovu and Woyessa, 2021). These changes in rainfall and temperature will decrease water availability by 13% by the end of the century in 2100 at national level (Hamududu and Ngoma, 2020).

The Zambezi River Basin comprises of 13 sub-basins namely Upper Zambezi, Kabompo, Lungwebungo, Luanginga, Barotse, and Chobe sub-basins in Upper Zambezi region, the Kariba, Mupata, Kafue, and Luangwa sub-basins in the Middle Zambezi region, and the Tete, Lake Malawi/Shire, and Zambezi Delta sub-basins Lower Zambezi region (Beilfuss, 2012). One of the sub-basins where the impacts of climate change are already being felt is the Barotse sub-basin that encompasses the Barotse Floodplain. According to a study by Banda *et al*., (2015), the Barotse floodplain and surrounding communities are experiencing adverse impacts of climate change, which include rising atmospheric temperatures, extreme heat, flooding, prolonged droughts, decreased precipitation, disrupted seasonal patterns, and reduced water availability. The adverse impacts of climate change have negatively affected the rural water supply system, reliant on natural sources which are highly susceptible to extreme weather events, such as droughts and floods. In addition to high dependence on natural water sources, rural communities have low adaptive capacity characterized by lack of resources, inadequate infrastructure, and high social vulnerability (Hamududu and Ngoma, 2020). Social vulnerability is the extent to which a system is susceptible to hazards due to the interaction of socio-economic, cultural, political and demographic factors (Dumenu and Takam Tiamgne, 2020; Spielman et al., 2020) Therefore, there is need to assess the social vulnerability of the rural communities around the Barotse Floodplain to climate change impacts on water resources and identify adaptation options that can help them cope with the impacts. This can help rural communities in the Barotse Floodplain build resilience and ensure water security in the face of climate change and its impacts.

1.1 Problem Statement

Climate change is altering hydrological patterns, leading to extreme weather events such as prolonged droughts, intense floods, and shifts in precipitation patterns *(Satoh et al*., 2022; Shrestha *et al.*, 2021; Tabari, 2020) threatening rural water supply systems in the Barotse Floodplain. Rural communities around the Barotse floodplain face significant risks that include water scarcity and contamination, exacerbated by limited resources, inadequate infrastructure, and social vulnerability. This has adversely affected the rural communities in the Barotse floodplain as rural water supply systems are crucial for their livelihoods and well-being.

Historically, local communities have effectively adapted to climate change impacts on water resources by employing indigenous strategies such as water harvesting, well deepening, and strategic relocation to areas with abundant water resources (Banda et al., 2015). However, the current magnitude of climatic changes, combined with their low adaptive capacity, has hindered their ability to respond effectively, exacerbating the challenges they face (Semba *et al.*, 2020). The social vulnerabilities of these communities characterised by limited resources, inadequate infrastructure, and reliance on natural resources intensifies the difficulties in adapting to climate impacts on water supplies (Hamududu and Ngoma, 2020). Vulnerable populations, such as women, children, and marginalized groups, are disproportionately affected by these risks and the increasing frequency and severity of climate-related events.

Hence, there is need to assess the specific socioeconomic vulnerabilities experienced within these communities that limit their capacity to adapt to the impacts of climate change on water resources and identify the adaptation options available to enhance their resilience against climate change impacts on water resources. Recognizing vulnerability factors and identifying context-specific adaptation strategies is crucial for sustainable water management and supply. This is because vulnerability assessments inform decision-makers about areas that need attention, resources, and support, whilst identifying adaptation options helps tailor interventions to specific community needs, maximizing effectiveness ensuring water security in the face of climate change.

This study assessed the social vulnerability of the rural communities in the Barotse floodplain and explored adaptation options to enhance their resilience against impacts of climate change on water resources.

1.2 Aim

The aim of this study was to investigate the susceptibility of rural communities in the Barotse Floodplains to climatic hazards affecting rural water supply.

1.3 Objectives

The objectives of this study were:

i. To assess the social vulnerability of rural communities in the Barotse floodplain to climatic hazards affecting rural water supply.
ii. To investigate the specific social risks associated with climatic hazards affecting rural water supply.
iii. To explore the existing adaptation strategies employed by rural communities in response to climatic hazards affecting water supply.
iv. To identify adaptation options that can enhance the communities' resilience to climatic hazards affecting water supply.

1.4 Research Questions

The objectives of the study were met using the following research questions.

i. What is the social vulnerability of the rural communities in the Barotse floodplains to the impacts of climate change on rural water supply?
ii. What are the key factors contributing to the social vulnerability of rural communities in the Barotse Floodplain to the impacts of climate change on water resources?
iii. What are the specific risks faced by the rural communities in relation to climatic hazards affecting rural water supply?

iv. What strategies are currently being employed to respond to climate change impacts on rural water supply?
v. Which adaptation options can enhance the communities' resilience to climatic hazards affecting water supply?

1.5 Significance of the study

Studies conducted in the Barotse floodplain catchment show that the negative impacts of climate change which include increase in atmospheric temperature and excessive heat in the plains, floods, prolonged dry spells, reduction in precipitation, unexpected changes in seasons and their durations and reduction in water supply are already being experienced (Banda *et al*., 2015). In addition, studies conducted in the Zambezi River Basin predict rising temperatures, decreasing precipitation and more variable seasons, which may lead to extended drought periods and more severe floods (Ndhlovu and Woyessa, 2021). These impacts pose significant risks to rural water supply systems as they threaten water availability at sustainable quality and quantities (Kumar, 2016). Rural communities in the Barotse floodplain are vulnerable to the impacts of climate change on water resources as they have limited resources, inadequate infrastructure, and depend on natural resources which exacerbates the challenges they face in adapting to climatic hazards affecting their water supplies (Hamududu and Ngoma, 2020). Hence, there is need to understand the factors contributing to their vulnerability and identify context-specific adaptation strategies that ensure sustainability of water resources in the face of climatic hazards affecting rural water supplies.

Therefore, this study investigated the social vulnerability of rural communities in the Barotse floodplain to the impacts of climate change on water resources and identified factors that contribute to their susceptibility to the impacts. This is important in designing proper adaptation strategies which are based on a solid understanding of local vulnerability and their adaptive capacity that will address specific local level needs and avoid one-size-fit-all measures. The study also explored existing adaptation options currently being employed and identified new adaptation options that can be employed by the rural communities in the Barotse floodplain to respond to the impacts of climate change on water resources. Development of adaptation strategies can be used to empower communities to integrate their indigenous knowledge and scientific knowledge to plan for and cope with climate change impacts on water resources increasing their resilience to the impacts. Results from this study can also be incorporated into national climate change policies which might be helpful to better understand climate change, its impacts on water resources and local strategies that could be used to mitigate the impacts. Findings from this can contribute to evidence-based decision-making, policy formulation, and the development of targeted interventions to support sustainable water supply and climate change adaptation in rural areas of the Barotse floodplain.

1.6 Organization of the Dissertation

Chapter one outlines the background of the study, the problem statement, objectives of the study, research questions and the significance of the study. Chapter two reviews the literature on climatic hazards affecting water resources, the vulnerability of various communities to the impacts of climate change on water resources and adaptation measures being implemented to cope with the impacts of climate change on water resources. The chapter also reviews climate change impacts on water resources in Zambia, in the Upper Zambezi River Catchment Area and Barotse floodplain. Chapter three outlines the study area in terms of location and the physical and socio-economic characteristics. Chapter four presents the methodology used in data collection and further outlines the analytical techniques that were used. Chapter Five presents the results of the study. Chapter six discusses and interprets the results of the study. Chapter seven concludes the study and makes recommendations based on the findings of the study.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter outlines the theoretical framework of the research and reviews climate change and its impacts on water resources in Africa and Zambia, vulnerability of rural communities and adaptation to climate change impacts on water resources.

2.1 Theoretical Framework

This study was guided by the adaptation and social vulnerability theories. The adaptation theory provides a systematic approach to analyse and address the challenges posed by climate change (Eisenack and Stecker, 2012). Teshome, (2018) states that to address climate change induced impacts it is important to assess the climatic conditions, the risks and vulnerabilities, the interconnectedness of social-ecological systems and adaptation mechanisms.

The history and development of adaptation theory in climate change context can be traced back to 1988 when the Intergovernmental Panel on Climate Change (IPCC) was established after the need to address the impacts of climate change and develop strategies to adapt to them was recognised. The IPCC's First Assessment Report in 1990 included discussions on the need for adaptation to climate change. As the impacts of climate change become increasingly evident, it is crucial to develop effective adaptation strategies that minimizes negative impacts and maximizes the potential benefits of climate change (Rawlins and Kalaba, 2021). Teshome, (2018, p. 152) defined adaptation as "actions targeted at the vulnerable system in response to actual or expected climate stimuli with the objective of moderating harm from climate change and exploiting opportunities brought about by climate change". Adaptation is an essential component of climate change impact and vulnerability assessment and is one of the policy options in response to climate change impacts. It is one of the two fundamental societal response options to the risks posed by anthropogenic climate change.

The social vulnerability theory describes combinations of social, cultural, economic, political, and institutional processes that shape the differential experience of hazards (Spielman *et al*., 2020). Dumenu and Takam Tiamgne, (2020) defines social vulnerability to climate change as "the degree to which a system is susceptible to the effects of climate change due to the interaction of socio-economic and demographic factors". Social vulnerability theory explores the social dimensions of vulnerability and the unequal distribution of risks and impacts by examining how social systems, such as communities, households, and individuals, are exposed to hazards, their sensitivity to those hazards, and their adaptive capacity. It also highlights that certain populations, such as the poor, marginalized communities, indigenous peoples, women, and the elderly, are more vulnerable to climate change impacts due to their limited resources, social inequalities, and limited access to information and decision-making processes.

The theory uses a quantitative indicator called the Social Vulnerability Index (SVI) which was developed through a review of hazard case studies. SVI is frequently used when comparing geographic units in terms of their relative levels of vulnerability, where the upper and lower bounds of the index correspond to the highest and lowest vulnerability levels in a study area. The SVI is a quantitative indicator with values ranging between 0 and 1. 0 is the lowest value and represents the lowest vulnerability level in a study area. On the other hand, 1 is the highest value and represents the highest vulnerability levels in a study area. Hence, the lower the SVI value the lower the vulnerability and the higher the SVI value the higher the vulnerability (Dumenu and Takam Tiamgne, 2020). SVI was originally constructed as a general environmental hazards' vulnerability measure for the United States of America but has since evolved to have hazard and geographic context-specific forms, including local jurisdictions state-level mitigation planning metropolitan comparisons international applications preparedness for specific hazards and for disaster recovery.

Both theories are important in addressing the impacts of climate change on vulnerable populations. In this study the social vulnerability theory was important in assessing the various factors that contributes to the social vulnerability or reduces the probability of adaptation to the climatic hazards affecting rural water supplies in the Barotse floodplain. This study adopted 11 indicators which are household size, household head gender, literacy level, income level, climate sensitive occupation, access to climate change information, social networks, access to community benefits, dependence on natural water sources, reliability of the source of water and TV or radio ownership to calculate SVI. The indicators are described and explained in Table 1.

Table 1: Social vulnerability factors, Indicators and indicator-vulnerability functional relationship

Vulnerability Factors (Major Components)	Indicators (Sub-components	Description of Sub-components	Impact on vulnerability	Source
Demographic	Household size	The average number of household members in each ward	The higher the household size the greater the level of vulnerability	(Dumenu and Obeng, 2016; Dumenu and Takam Tiamgne, 2020; Sahoo and Sridevi, 2021)
	Household head gender	Percentage of households that are headed by females	Female headed households are more vulnerable than male headed households	(Sam *et al*., 2017; Tasnuva *et al*., 2021)
	Literacy level	Percentage of households where the head has attained at least primary school	Households with a household head having education below the primary level are more vulnerable	(Dumenu and Obeng, 2016; Dumenu and Takam Tiamgne, 2020; Sahoo and Sridevi, 2021)
Economic	Household Income level	The average income of households in each ward	The lower the level of income the higher the vulnerability	(Dumenu and Takam Tiamgne, 2020)
	Climate sensitive occupation	Percentage of households reporting agriculture or fishing as the only source of income	Households dependent on agriculture or fishing are more likely to be vulnerable to the reduction of crop and fish production	(Dumenu and Obeng, 2016; Sahoo and Sridevi, 2021a)
Social	Access to climate change information	Percentage of households with access to climate change information	Households with access to climate change information are less vulnerable to climate change	(Dumenu and Obeng, 2016; Dumenu and Takam Tiamgne, 2020; Sahoo and Sridevi, 2021)
	Social Networks	Percentage of households that can seek help or obtain help from social networks	Households that can obtain help from others in times of need (social networks) are less vulnerable	(Pandey *et al*., 2015)
	Access to community benefits	Percentage of households with access to community projects or benefits	Households with access to community projects and benefits are less vulnerable	(Sahoo and Sridevi, 2021)
	Dependence on natural water sources	Percentage of households using natural water source	Natural water sources are sensitive to climate change and its impacts. Households relying on natural sources are more vulnerable	(Pandey *et al*., 2015; Sam *et al*., 2017)
	Reliable source of water	Percentage of households with a reliable source of water	Households that have a reliable source of water are less vulnerable	(Sam *et al*., 2017)
	TV or radio ownership	Percentage of households that own a TV or a radio	Households that own these assets are more likely to be less vulnerable as have access to climate change information	(Dumenu and Takam Tiamgne, 2020; Tasnuva *et al*., 2021)

The adaptation theory, on the other hand, was critical in exploring the existing adaptation options and strategies that are currently being employed in the area to reduce the adverse effects of climate change on water resources. The theory was also used to identify potential adaptation strategies to climate change impacts on water resources. These strategies are in response to already observed climate change impacts (reactive adaptation) and in anticipation of future climate change impacts on water resources as well (proactive adaptation). Reactive adaptation takes place after impacts of climate change have been observed or felt and the adaptation is informed by direct experience, and resources are targeted to known risks. On the other hand, proactive adaptation takes place before the impacts of climate change are observed or felt. It is forward-looking and considers the inherent uncertainties associated with anticipating change. Reactive approaches help vulnerable populations recover from unavoidable impacts and proactive actions reduce future risk.

2.2 Climate Change

Research have ascertained that the earth's climate is changing and the impacts that are being experienced in many places of the globe are more likely to become severe as changes in climate are expected to intensify (Asfaw *et al*., 2021). Shewmake, (2008) states that climate change is expected to cause an increase in drastic weather events. This is supported by Alfani *et al*., (2019) who state that severe climatic events such as droughts, floods, and extreme temperatures are expected to increase in frequency and intensity over time. Research also indicates that if carbon emissions are not curbed immediately to keep global warming below 2°C, we are headed for irreversible and catastrophic conditions (Asfaw et al., 2021). The impacts of climate change are already being felt in every inhabited continent and in the oceans and there is a growing concern that global climate change is reaching a point where certain parts of the earth system are starting to pass dangerous climate tipping points (Winkelmann *et al*., 2022).

2.4 Climatic hazards and water resources

The water sector is one of the sectors that is vulnerable to climatic hazards as water and climate change are closely connected. Climate change impacts on the water sector have a ripple effect on other sectors like agriculture, industrial activities, health (Nkhonjera and Dinka, 2017). Climate change is affecting the world's water in various ways, and extreme weather events like intense rainfall, extreme storms, dry spells, extreme hot days, increase in frequency and severity of drought and floods are making water more scarce, unpredictable, or polluted (Nkhonjera and Dinka, 2017; Ruppel and Ruppel-Schlichting, 2013). It is estimated that these impacts will escalate the existing situation in countries already threatened with water insecurity whereas similar problems threaten areas that have not been severely affected (Sarkodie *et al*., 2022). These impacts compromise water quality as well as accessibility as they may destroy water supply infrastructure and diminish the available water resources hence, affecting water reliability, physical accessibility, and affordability. (Kohlitz *et al*., 2020). According to Ruppel and Ruppel-Schlichting, (2013) it is predicted that the impacts of climate change could increase the number of people facing water scarcity by 1.8 billion by 2080.

2.5 Vulnerability and adaptation to climate change impacts on water resources.

People living in rural areas are considered to be more vulnerable to the impacts of climate change on water supplies as climate and water experts believe that rural communities will experience major climate change impacts through water supplies (Kohlitz *et al*., 2020). Pandey *et al*., (2015) conducted a study to assess the climate related water vulnerability of households in mountainous region of Uttarakhand, India using the Climate Vulnerability Index for Water (CVIW). The results of the study showed that rural households had a higher water vulnerability than urban households. They attributed the higher vulnerability of the rural households to heightened sensitivity and exposure of the rural region compared to the urban region. Kohlitz *et al*., (2020) state that climate change projections vary across regions of the world, but it is likely that climate change will worsen these impacts on rural water safety in most places. In a review that was conducted by Joshua, (2021) on the impacts of extreme climate events on water quality, water access and availability within northern Nigeria, it was found that extreme climate events are continually impacting water access and quality within northern Nigeria with rural communities being worst affected because of inequalities amongst and within rural people. Climate change impacts on rural water supplies threaten water safety in rural areas and these impacts will likely worsen as climate change accelerates (Kohlitz *et al*., 2020). Rankoana, (2020) conducted another study to explore the impacts of climate change on water resources in a rural community in Limpopo Province, South Africa. The results of the study showed that the major sources of water (Mutale River and community borehole) are being negatively affected by the impacts of climate change resulting in unsustainable water supply. Rural populations are highly vulnerable to the impacts of climate change as they have high levels of exposure to climate related hazards and a low capacity to respond to the impacts. Rural communities depend on the direct use of natural resources and have less buffer capacity to cope with adverse effects of climate change making them more vulnerable to climate change impacts (Bauer and Scholz, 2010).

Therefore, there is need to design and formulate suitable as well as appropriate adaptation strategies which help to modify existing water system (comprising water infrastructure and technologies, water resources, and their management) and human systems so that they can withstand and resist climate shocks and their impacts on rural water supplies (Kohlitz *et al*., 2020; Tofu *et al*., 2022). To formulate the adaptation strategies, it is critical to understand the nature of climate change impacts on rural water supplies being experienced by the local people, their vulnerability to the impacts and their indigenous adaptive responses (Tofu *et al*., 2022). Assessing local level impacts, vulnerability and adaptation is critical for the development of policy measures that address specific local level needs and avoid one-size-fit-all measures that often result from national scale climate change assessment (Dumenu and Obeng, 2016). Assessing vulnerability is important in designing proper adaptation strategies which will be based on a solid understanding of local vulnerability, including their adaptive capacity together with exposure and sensitivity (Asfaw *et al*., 2021).

Vulnerability is the degree to which a system is susceptible to or unable to cope with the adverse effects of climate change including climate variability and extremes (Tesso *et al*., 2012). There are various factors which influence vulnerability to climate change and variability and these include social, economic, demographic, institutional and political factors (Dumenu and Takam Tiamgne, 2020). Vulnerability assessment can help address the questions about who and what is vulnerable, to what are they vulnerable, their degree of vulnerability, the causes of their vulnerability, and what responses can lessen their vulnerability (Asfaw *et al.,* 2021). This is because climate change impacts will not affect water safety for people living in rural areas to the same level, even for people living in the same community (Kohlitz *et al*., 2020). This knowledge can help ascertain options that promote or constraint adaptation or mitigation measures. It also informs policymakers on devising interventions that can help households and communities improve their capacities to adapt to climate change impacts and reduce their vulnerability and underlying socio-economic and demographic factors that influence social groups, households, and communities' vulnerability to climate change (Dumenu and Takam Tiamgne, 2020). This can assist policy makers and development actors in guiding where to invest to reduce vulnerability and enhance the adaptive capacity of households against the adverse effects of climate change-induced shocks on water supplies (Tofu *et al*., 2022).

Understanding the communities' indigenous adaptive responses helps to determine how local people are informed by indigenous knowledge to make decisions in response to both current and forecasted climate change impacts on water resources (Mapfumo *et al*., 2015). In local communities, adoption of indigenous adaptation strategies is determined by various factors such as economic, social, political, and institutional environments as well as the type of risk being faced and the available adaptation options. (Aryal *et al*., 2021). Understanding how communities adapt and the factors influencing their adaptation choices is important in designing future adaptation policies. Hence, combining both indigenous and scientific knowledge on climate change and science-based forecasts helps to produce robust climate forecasting systems that help in the design of effective adaptation strategies (Semba *et al*., 2020).

2.6 Climate change and water resources in Africa and Southern Africa.

The African continent is one of the most vulnerable continents to climate change with countries such as Nigeria (Joshua, 2021), Zambia (Banda et al., 2015; Dumenu and Takam Tiamgne, 2020; Milupi et al., 2019), Zimbabwe (Mudombi and Muchie, 2013; Nyamwanza, 2018) and South Africa (Patrick, 2021; Rankoana, 2020) already experiencing the impacts of climate change. African countries are particularly vulnerable to climate change because of multiple stresses and low adaptive capacity, lack of financial, institutional and technological capacity, and overdependence on rainfed agriculture (Mekuyie, 2021; Ruppel and Ruppel-Schlichting, 2013). Climate change is expected to exacerbate Africa's struggles with strained water resources and food security (Shewmake, 2008). The IPCC Fourth Assessment report review of climate model projections shows a consistent pattern of progressive arid warming of the climate in all regions of Africa, but a much less consistent pattern for rainfall (MacDonald *et al.*, 2011). The Southern African region is also projected to suffer a decrease in water resources due to climate change (Ruppel and Ruppel-Schlichting, 2013). Projections for Southern Africa have reflected a much higher warming of 2°C by the mid-century (2050) and 3°C increase by the end of the century (Semba *et al*., 2020).

The Southern African Development Community (SADC) region is particularly vulnerable to the impacts of climate change as it is one of the poorest in the world and has experienced unusual weather patterns over the past years in terms of drought and flooding (Ruppel and Ruppel-Schlichting, 2013). Studies have also shown that the Southern African region is warming up faster than the global average and climate models and scenarios indicate that the impacts of warming will be more severe in the region as it is most likely to become warmer and drier (Bauer and Scholz, 2010). Hence, the region is at risk of reaching climate tipping points faster than other regions. The region contains about a tenth of the global population that is effectively decoupled from overall global progress, socioeconomically representing one of the world's poorest and most vulnerable regions (Joshua, 2021). About half of the Southern African population live in rural areas most of them as small-scale farmers and these are typically the most vulnerable to the adverse impacts of climate change on water resources (Bauer and Scholz, 2010). Assessments of water availability, including water stress and water drainage, show that parts of southern Africa are highly vulnerable to climate variability and change (Ruppel and Ruppel-Schlichting, 2013).

2.7 Climate change impacts on water resources in Zambia

Zambia is not immune to the impacts of climate change and is already experiencing climate change induced hazards which include frequent drought, prolonged dry spells, seasonal and flash floods, and extreme temperatures (Banda *et al*., 2015; Dumenu and Takam Tiamgne, 2020; Milupi *et al*., 2019). These impacts have had severe effects on the water sector resulting in adverse consequences on water security, water quality, and sustainable livelihoods of rural communities (Dumenu and Takam Tiamgne, 2020). Rawlins and Kalaba, (2021) state that vulnerability to climate extremes such as droughts and floods is also increasing, posing a significant threat to water security in the country. Rawlins and Kalaba, (2021) noted that rainfall has decreased by an average rate of 1.9 mm/month (2.3%) per decade since 1960, and that the rainfall season has become shorter and more difficult to predict with fewer, but more intense rainfall events.

Studies conducted in the Zambezi River Basin have predicted rising temperatures, decreasing precipitation, extended drought periods and severe floods (Hamududu and Ngoma, 2020; Ndhlovu and Woyessa, 2021).It has been noted that floods are gradually increasing in frequency and intensity especially in regions around the Zambezi River leading to siltation and segmentation of rivers and streams thereby reducing their capacity to hold water (Milupi *et al*., 2019). A study by, Banda *et al.*, (2015) found that communities around the Barotse Floodplains have started experiencing the negative impacts of climate change which include increase in atmospheric temperature and excessive heat in the plains, floods, prolonged dry spells, reduction in precipitation, unexpected changes in seasons and their durations and reduction in water supply. For years, local communities have depended on natural resources for their livelihoods and food security relying on indigenous knowledge to predict weather patterns, strategize on coping, and adaptation measures, however the magnitude of changes currently taking place has limited their capacity to effectively do so (Semba *et al*., 2020).

2.8 Summary of Chapter

Climatic hazards have presented diverse challenges in the water sector because of its sensitivity and how it is interconnected with climate. Climatic hazards such as prolonged droughts and extreme temperatures affect the quality, quantity, availability, and accessibility of water resources. In addition, rural communities are highly vulnerable to the impacts of climate change on water resources because of their low adaptive capacity.

CHAPTER THREE

STUDY AREA

3.0 Introduction

The study was conducted in rural communities within Mongu District in the Barotse Floodplain Catchment. The rural communities were Nakanya, Lealui and Malengwa villages. This chapter is a description of the study area's location. It highlights the study area's biophysical characteristics, demographics as well as the socio-economic characteristics at two levels: study area (Barotse floodplain) and study district (Mongu district).

3.1 Barotse Floodplains

3.1.1 Geographical Characteristics

The Barotse Floodplain is a designated Wetland of International Importance under the Ramsar Convention (Beilfuss, 2012) located in the Western province of Zambia (Figure1) and is part of the Upper Zambezi River Basin (Chomba *et al*., 2022; Moore *et al*., 2008; Zimba *et al*., 2018). It is a relatively flat plateau predominantly covered by Kalahari sands stretching from Lukulu, at the confluence of the Zambezi with Kabompo River, in the north to Senanga in the south a stretch of about 230 km (Zimba *et al*., 2018). The Barotse floodplain lies between 13 and 17° South and 22–24° East of western Zambia (Banda *et al*., 2023; Zimba *et al*., 2018). The elevation over the floodplain ranges from 900 m above sea level in the southern part, at Senanga to about 1192 m above sea level in the northeastern part, at Lukulu. The floodplain averages 30 km width along most of its length and is about 50 km at the widest north of Mongu town, the western province headquarters situated at its edge. The Barotse floodplain receives an annual rainfall of 810mm (Midgley *et al.*, 2012)

3.1.2 Socioeconomic Characteristics

The Lozi people are the inhabitants of the Barotse floodplain and are under the traditional leadership of the Barotse Royal Establishment (BRE) that is led by the King, the Litunga (Owner of the Land) and is assisted by the ministers locally called Indunas (Milupi *et al*., 2019). The Lozi are dependent on mixed livelihoods, combining crop farming, livestock, fishing, and natural resource exploitation with over half of the population involved in fishing activities

(Midgley *et al*., 2012). Crops grown in the Barotse floodplain area include rice, maize, sorghum, millet and cassava grown on the upland areas (Milupi *et al*., 2019).

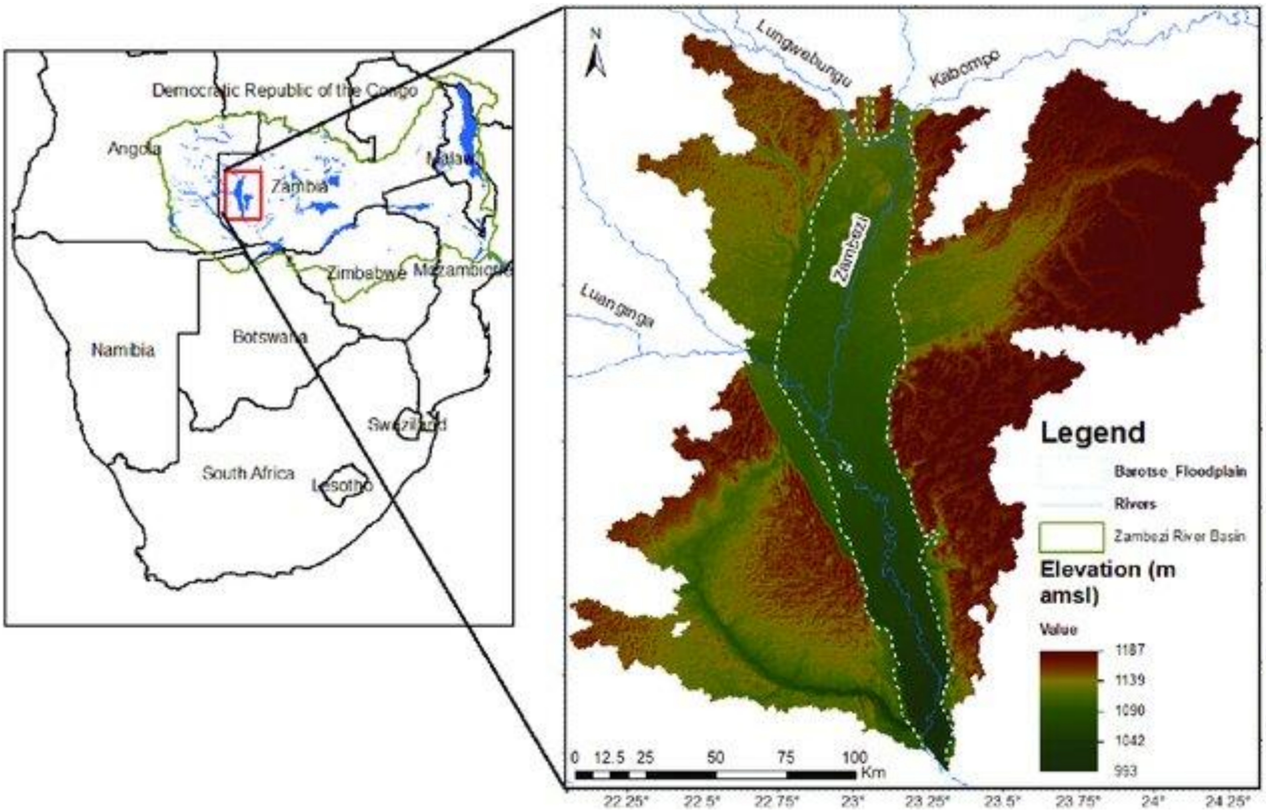

Figure 1: Map of the Barotse Flood Plains

Source: Chomba et al., (2022)

3.2 Mongu District

3.2.1 Location and Administration

Mongu is the provincial capital for Zambia's Western Province and is located approximately 600 Km west of Lusaka, capital of Zambia (Figure 2). Mongu District lies between longitudes 22^{o} 49' and 24^{o} 00' east and Latitudes 14^{o} 37' and 15^{o} 49' south (Mongu Municipal Council.) at 1080m above sea level (Privette *et al.*, 2004). It shares boundaries with Kalabo in the northwest, Kaoma in the northeast, Limulunga in the southeast and Luampa in the east, Senanga in the South and Nalolo in the south-west. Traditionally the district is governed by The Baroste Royal Establishment headed by the Litunga, who is assisted by senior chiefs, Silalo Indunas and headmen. The district is governed by both the local government headed by a mayor and central governance headed by a district commissioner.

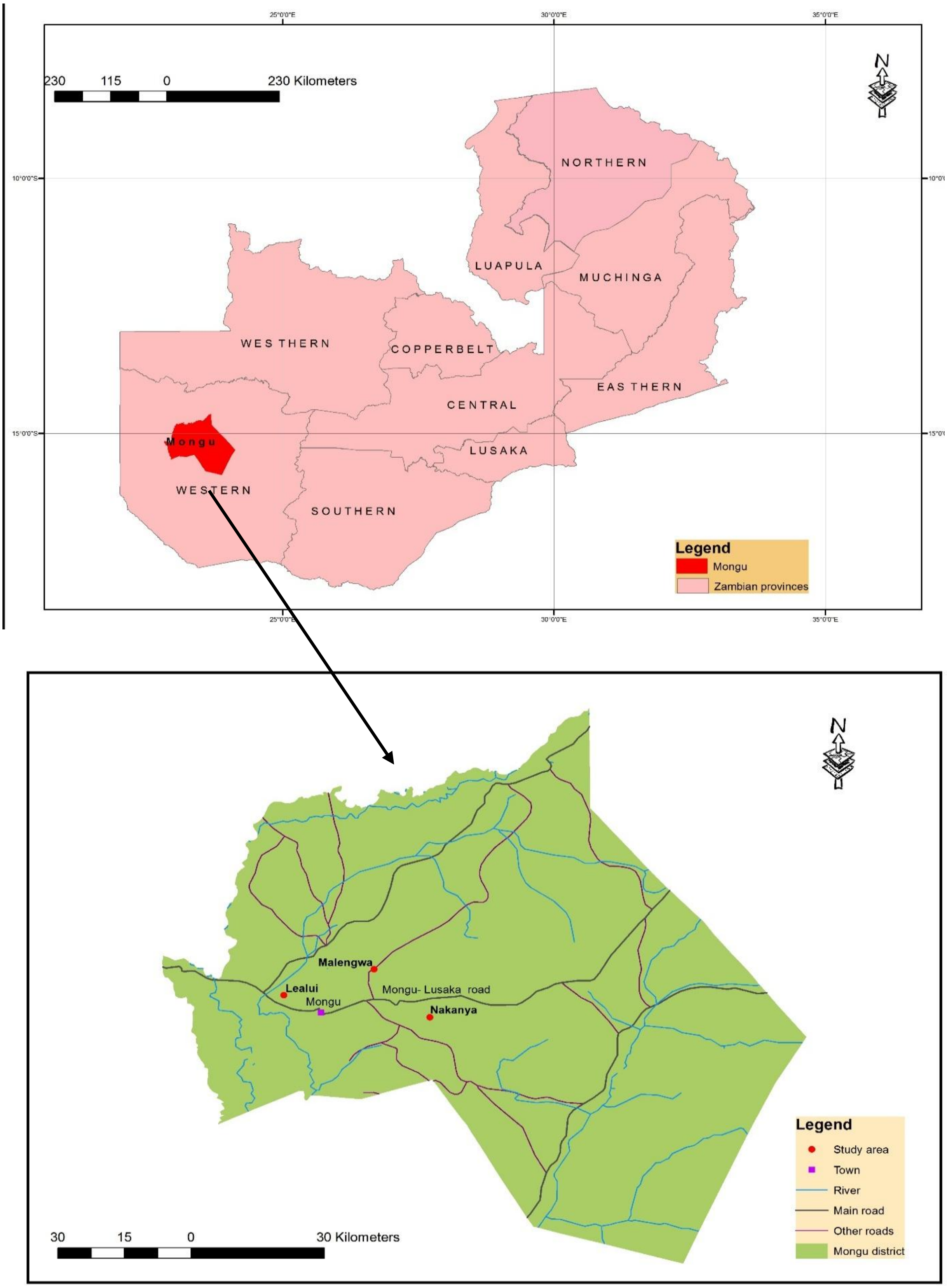

Figure 2: Map of Mongu District showing the study sites

Source: Cartography Unit, Department of Geography and Environmental Studies, University of Zambia, 2025

3.2.2 Demographic Characteristics

Mongu District covers an area of 5959.8km^2 and has 27 wards that are split into 2 constituencies namely Mongu Central and Nalikwanda. The three study sites are among the 27 wards. According to Mongu Municipal Council, as of the 2022 census Mongu district is home to 36,605 households (26,140 rural and 10,465 urban) housing a total population 197,816 people (93,540 males and 104,276 females). The population was projected to be at 212,584 people by 2024. About 59% of the population lives in rural whilst 41% of the population resides in urban areas. As of the 2022 census the population density of Mongu district was at 33.2 people/km^2 projected to be at 35.7people/km^2 by 2024.

3.2.3 Biophysical Characteristics

3.2.3.1 Climate

Mongu district receives mean annual rainfall of between 800mm and 1000mm and has a crop growing period of 100 to 150 days. The average temperature in Mongu district varies between 10 degrees Celsius in July which is the coldest month to 38 degrees Celsius in October which is the hottest month.

3.2.3.2 Soils

The district is predominantly covered by Kalahari sands and poorly drained clay soils in valley dambos and hydromorphic plains. According to Akkermans *et al*., (2012) the sandy soils are well drained, deep, and hydrologically highly conductive.

3.2.3.3 Vegetation

The dominant landcover types are woodland, dambo grassland, agriculture and floodplain (Anyamba *et al*., 2003). The woodland is characterised by the Miombo woodland dominated by *Brachystegia spiciformis* with sparse woody understory (Privette *et al*., 2004; Scholes *et al*., 2002).

3.2.4 Socioeconomic Characteristics

The residents of Mongu District engage in various economic activities which include agriculture (livestock rearing and food crop production), horticultural production, fishing, beer brewing, charcoal burning, crafts, and trading in agricultural products Agriculture is the major source of livelihood for most people in the district especially in the rural communities with over 70 % of the households dependent on agriculture. The agricultural production areas are Mongu East and the Baroste plains with rain-fed agricultural and wetland farming being the predominant type of farming practices. Crops grown in Mongu district are maize, cassava, rice, legumes, millet, sorghum groundnuts and sweet potatoes. Horticultural production involves vegetables like tomatoes, rape, cabbage and tree crops like cashew, avocado, citrus fruits.

3.3 Reasons for the selection of the study area.

The Barotse floodplain was chosen as the study area for this study as it has been identified as one of the climate change hotspots in Zambia and Southern Africa. Research conducted in the Barotse floodplain catchment area reveals that the region is already experiencing the adverse effects of climate change, including rising temperatures, excessive heat, floods, prolonged droughts, reduced precipitation, unpredictable seasonal patterns, and decreased water supply. (Banda *et al*., 2015). These impacts pose significant risks to rural water supply systems by threatening water availability and accessibility. In addition, the rural communities in the Barotse floodplains catchment area have limited resources, inadequate infrastructure, and depend on natural resources which exacerbate the challenges they face in adapting to climatic hazards affecting their water supplies.

CHAPTER FOUR

METHODOLOGY

4.0 Introduction

This chapter outlines the epistemological and ontological positions that were adopted for the study. It also describes the research approach and methodology that was used to collect the data. Finally, it outlines how the data that was collected was analysed.

4.1 Epistemological and ontological positions

According to Smith, (2012) Ontology is a branch of philosophy in science of what is, of the kinds and structures of objects, properties, events, processes and relations in every area of reality. In a broader sense ontology refers to the study of what may exist (Smith, 2012). It deals with the nature of reality, existence, and knowledge. On the other hand, epistemology is concerned with the theory of knowledge, regarding its methods, validation and the possible ways of gaining knowledge of social reality (Grix, 2002). Epistemological assumptions influence the choice of methods to be used in the research as well as the strengths and limitations of subsequent research findings (Saunders *et al*., 2009). Ontology and epistemology are closely related, and they both form the basis upon which a research approach is adopted during a study.

The research was based on pragmatism ontological and epistemological positions which are philosophies that allows mixing paradigms, assumptions, approaches and methods of data collection and analysis (Maarouf, 2019). The pragmatism position was important in bridging the gap between the practical application of the Social Vulnerability Index and the theoretical understanding of the unique experiences of the rural communities in Mongu to the impacts of climate change on rural water supplies and the adaptation strategies they are implementing. Pragmatism helped the researcher understand the social vulnerabilities of the rural communities in Mongu District to climate change impacts on rural water supplies and the adaptation options they are currently implementing. Adoption of pragmatism allowed the researcher to use a mixed method research approach by combining quantitative and qualitative research approaches as the study was both subjective and objective (Maarouf, 2019). An objective approach was important for assessing the social vulnerability of the rural communities whilst a subjective approach was important for identifying the risks they are facing because of climate change impacts on water resources and the adaptation strategies they are implementing. The mixed method approach also helped establish a relationship between the social vulnerability of the rural communities in Mongu District and the strategies they are implementing to cope with the impacts of climate change on water resources in the area.

4.2 Research Design

This study employed a convergent parallel mixed method research design to gain an in-depth understanding of the social vulnerability and adaptation options being employed by the rural communities in Mongu District. The convergent parallel mixed method research design uses a mixed method approach whereby it incorporates quantitative data collection tools like questionnaires and qualitative data collection tools like in-depth interviews (Akash and Aram, 2021). A mixed method approach was important for providing a comprehensive understanding of rural communities' social vulnerability to climate change impacts on water resources and the factors that are influencing their social vulnerability. Combining quantitative and qualitative data helped to enhance validity and reliability through data triangulation as each data type complemented and informed the other. The qualitative and quantitative data were collected concurrently in the same phase of the research. Key informant interviews and a household survey consisting of a semi-structured structured interview were used to collect the data. Key informant interviews and the open-ended questions from the semi-structured interview were used to collect qualitative data on the risks being faced by the rural communities and the adaptation strategies being implemented to cope with the impacts of climate change on rural water supplies. The closed ended questions were used to collect quantitative data on the demographics, economic and social indicators of social vulnerability. The study gave equal priority for both the quantitative data and qualitative data, analyzed the data independently and interpreted the results together by comparing the results and converging for overall interpretation (Akash and Aram, 2021; Demir and Pismek, 2018).

4.3 Sampling

A multistage sampling technique was used for the study whereby the villages from which the data was collected were purposively sampled and the households for the household survey randomly sampled. Nakanya, Lealiu, and Malengwa villages were purposively selected for the study based on their geographical location. Sampling villages from different geographic regions allowed the researcher to appreciate the differences in social vulnerability amongst the geographical regions. To determine the sample size the following formula adopted from Israel, (2013) was used:

$$n = \frac{N}{1+N(e)^2} \quad \text{Equation 1}$$

Where n is the sample size, N is the population size (total number of rural households), and e is the level of precision. The researcher used 7% level of precision and total number for the rural households of 26140. This formula yielded a sample size of 203 rural households. However, the data was collected from 205 households (81 households in Nakanya village, 75 households in Lealiu village and 49 households in Malengwa village). Of the 205 respondents that were interviewed 108 were females and 97 were males. The sample sizes differed across study sites due to unforeseen circumstances during data collection. In Malengwa village the researcher and the research assistants encountered challenges in finding participants, resulting in a smaller sample size.

Six (6) key informants were purposively sampled for the study. The key informants were officers from local government, central government, department of water resources development, department of water supply and sanitation, western water and sewerage company and the meteorological department.

4.4 Data Collection Methods

4.4.1 Household Survey

Semi structured interviews were administered to the 205 sampled households by the trained research assistants during the household survey. The household survey covered three (3) villages namely Nakanya, Lealiu, and Malengwa villages.. Adams (2015) states that semi structured interviews are conducted conversationally with one respondent at a time, by employing a blend of closed- and open-ended questions which are often accompanied by follow-up why or how questions. Quantitative data was used to calculate the Social Vulnerability Index of each sampled village. Qualitative data gave a deeper understanding of the challenges being faced by the rural communities because of climate change impacts on rural water supply and the adaptation strategies they are implementing to minimize the challenges. The questions were translated from English to *Silozi* the language most used in the study area by the research assistants.

4.4.2 Key Informant Interviews

The key informant Interviews were conducted first before engagement with other research participants. This enabled the researcher to verify the effects of climate change on water resources in the area. The interviews aided in identifying the vulnerable communities, hence selection and mapping of the study area as well as sampling of households. The interviews also gave a general picture of the challenges being faced by the communities in the Barotse Floodplains catchment area in adapting to climatic hazards that are affecting rural water supplies, the adaptation options being used and their effectiveness in reducing negative effects of climate change on water resources.

The interviews with the department of water resources development, department of water supply and sanitation and western water and sewerage company officers helped in identifying adaptation options that can help ensure a sustainable water supply in the Barotse Floodplains in the face of climate change. These interviews also helped to assess the effectiveness and limitations of the current adaptation options being implemented by the rural communities in response to climate change's impacts on water resources.

Interviews with officers from the local government and central government helped the researcher assess the challenges being faced at community level because of climate change impacts on rural water supplies. The interviews also helped to inquire about any external support the communities are receiving to help them cope with the effects of climate change on water resources and the effectiveness of the support they have received, and to identify areas where the communities might need support.

4.5 Data Analysis

The research employed a mixed method approach whereby quantitative and qualitative data was collected. Therefore, the collected data was analyzed quantitatively as well as qualitatively. Data analysis is a process of transforming the collected data to make relevant conclusions to the subject under study.

4.5.1 Quantitative Data Analysis

This study adopted the Social Vulnerability Index and collected data on the social, economic and demographic factors of the rural communities (Dumenu and Takam Tiamgne, 2020; Sahoo and Sridevi, 2021). Data collected using the closed ended questions during the household survey was used to calculate the social vulnerability Index for each village. To calculate the

SVI 11 indicators which are household size, household head gender, literacy level, income level, climate sensitive occupation, access to climate change information, social networks, access to community benefits, dependence on natural water sources, reliability of the source of water and TV or radio ownership were used. The data for the indicators was collected on different scales and standardized or normalized using the following formulas adopted from (Dumenu and Takam Tiamgne, 2020; Sahoo and Sridevi, 2021):

$$IndexKf = \frac{Kmax - Kf}{Kmax - Kmin} \text{..Equation 2}$$

If the overall vulnerability was decreasing with the increase in value of indicators. Or

$$IndexKf = \frac{Kf - Kmin}{Kmax - Kmin} \text{..Equation 3}$$

If the overall vulnerability was increasing with the increase in value of indicators.

Kf is the original value of sub-component for each village and Kmax and Kmin are the maximum and minimum values of each subcomponent determined using data from all households and the sampled villages. For variables that show frequencies, for example, the percentage of households with access to reliable water, the minimum value was set at 0 and the maximum value at 100.

After standardization, the vulnerability index was computed using the formula:

$$SVI = \frac{1}{N}(DF + EF + SF) \text{ .... Equation 4}$$

N is the number of indicators, DF are the demographic factors, EF economic factors and SF social factors.

This equation was applied to all the sampled villages. The researcher assumed equal weights for the indicators. The computation of the SVI was conducted using Microsoft Excel.

4.5.2 Qualitative Data Analysis

The recordings from the key informant interviews were transcribed and the transcripts analysed thematically. The researcher familiarised themselves with the transcripts and highlighted similar responses which were then grouped together to form themes. Unique responses from the key informants that differed from others were clearly highlighted. According to Jason and Glenwick, (2016) thematic analysis is a method that is used to analyse qualitative data by searching for recurring ideas in a data set which will be referred to as themes. Themes may emerge multiple times within each interview and between interviews with different people (Jason and Glenwick, 2016). Data obtained from the open-ended questions of the semi structured interviews was also analysed thematically by identifying similar responses and grouping them into themes.

4.6 Validity and Reliability

Validity and reliability are used as measures of assessing the quality of research studies (Heale and Twycross, 2015) and help ensure credibility of research findings (Noble and Smith, 2015). Validity is defined as the extent to which a concept is accurately measured. To ensure validity of data in this research, data obtained from semi structured interviews was triangulated with key informant interviews. Reliability refers to the consistency and dependability of research measures by assessing whether the methods used produce consistent results. For reliability, appropriate sampling, data collection and analysis methods were employed for qualitative and quantitative approaches used in this study

4.7 Ethical Considerations

Ethical clearance was obtained from the Natural and Applied Sciences Research Ethics Committee at the Directorate of Research and Graduate Studies Committee the University of Zambia before proceeding with the data collection (Approval No. NASREC-2024-FEB – 017, Refer to Appendix C). Before undertaking this study, consent was sought from all participants who were to take part in this study. In addition, every participant was assured anonymity, and only willing respondents participated in the study. Participants were fully informed regarding the objective of the study, while they were assured that their answers would be kept confidential and solely used for academic purposes only. Participants were treated with respect, and they were informed that their participation was voluntary as the data to be collected was purely for academic purposes if they so wished, they could withdraw at any point during the interview.

CHAPTER FIVE

RESULTS

5.1 Introduction

This chapter presents results of the research study and is organized into sections using themes related to research objectives. The data and results for objective 1 were presented first followed by those for objectives 2, 3 and 4 as described below.

5.1.1 Demographics of the sample

The total number of households that were sampled for this research were 205 households (Malengwa village 49 households, Lealui village 75 households and Nakanya village 81 households). Of the 49 households that were interviewed in Malengwa village 26 (53%) were male headed whilst 23 (47%) were female headed. In Lealui 50 (67%) households were male headed whilst 25 (33%) were female headed. Finally, in Nakanya village 62 (77%) households were male headed whilst 19 (23%) were female headed.

5.2 Vulnerability of rural communities in Mongu

The results of the social vulnerability index (SVI) revealed that rural households in Nakanya village are the most vulnerable to climate change impacts on water resources having recorded an SVI of 0.52. This is followed by Lealui village which had an SVI of 0.45. The least vulnerable of the three villages is Malengwa village which recorded an SVI of 0.39. Table 2 presents the social vulnerability factors (major components) and their respective indicators (sub-components) that influenced the vulnerability of the households in the villages.

In terms of the social vulnerability factors economic factors largely influenced the vulnerability in all the villages as it had the highest values, followed by social factors with demographic factors being the least. However, Nakanya village recorded the highest indices for economic and social factors of 0.69 and 0.64 respectively which resulted in it recording the highest vulnerability. In Lealui village, the economic and social factors recorded indices of 0.66 and 0.45 respectively. In Malengwa village the economic and social factors recorded the least indices of 0.47 and 0.44 respectively which resulted to the least overall vulnerability.

Table 2: Indexed sub-components, major components and overall social vulnerability index of smallholder farmers in the three villages

Social vulnerability factors (major components)	**Indicators (subcomponents)**	**Sub-components indices**			**Major components index**		
		Malengwa	**Lealui**	**Nakanya**	**Malengwa**	**Lealui**	**Nakanya**
Demographic	Household size	0.22	0.34	0.45			
	Household head gender	0.47	0.33	0.23	0.26	0.23	0.25
	Literacy	0.08	0.03	0.06			
Economic	Income level	0.88	0.91	0.97			
	Climate sensitive occupation	0.06	0.41	0.40	0.47	0.66	0.69
Social	Access to climate change information	0.14	0.09	0.11			
	Social networks	0.53	0.63	0.77			
	Access to community benefits	0.80	0.80	0.72	0.44	0.45	0.64
	Dependence on natural water sources	0	0.36	0.68			
	Reliable Source of Water	0.65	0.32	0.78			
	Ownership of a TV or a radio	0.49	0.49	0.77			
	Overall social vulnerability index				0.39	0.45	0.52

Source: Field Data, 2024

5.3 Risks associated with climatic hazards affecting rural water supply.

5.3.1 Climate change impacts on water resources

The findings of the study reveal that 85% of the respondents in Lealui considered drought as the most severe climatic hazard that they have been experiencing because of climate change. In Malengwa and Nakanya 80% and 51% respectively of the respondents also considered drought as the most severe climatic hazard they have been experiencing. Drought has been considered the most severe climatic hazard because of the drastic effects it has had on water availability, water accessibility and crop as well as livestock production. Extremely high temperature was also considered as a severe climatic hazard being experienced with 35% of the respondents in Nakanya village considering it as the most severe. In Malengwa and Lealui villages 16% and 10% respectively considered extremely high temperature as the most severe climatic hazard they have been experiencing because of climate change. Just like drought high temperatures have also affected water availability and accessibility as most of the water sources have dried up because of the excessive heat. Crops have also dried because of the high temperatures. The summary of the climatic hazards being considered as the most severe and the key reasons for their severity are shown in table 3.

Table 3: Severe climatic hazards being experienced in the Barotse because of climate change

Climatic Hazard mentioned as severe	Precent mentioned			Key reasons for severity
	Malengwa	Lealui	Nakanya	
Drought	80%	85%	51%	Loss of crops and animals; Reduced water availability and accessibility; Hunger and starvation; Loss of sources of income.
Extremely high Temperatures	16%	10%	35%	Drying of water sources; Loss of crops; Reduced fish production
Low rainfall (dry spells)	4%	0%	7%	Loss of crops; Reduced water levels;
Excessive winds	0%	5%	7%	Destruction of houses

Source: Field Data, 2024

Climate change is negatively affecting the rural water supply of the Barotse floodplains in various ways. Increase in frequency and severity of drought is making water scarcer escalating water insecurity issues in the Barotse floodplains. This is noted from the responses that were obtained from the survey which was conducted. Almost all the respondents from the three villages mentioned that there has been a reduction in water availability and accessibility because of climate change. Communities in the rural parts of the Barotse floodplains do not have access to piped water and rely on surface water from streams or ground water from shallow wells or boreholes. Some of the streams, wells and boreholes where people used to access water from have dried because of the climate change induced drought and extreme high temperatures.

It was also noted that climate change has led to a shift in the rainfall patterns. This has altered ground water recharge leading to decreased water levels resulting in an increased iron concentration in ground water. Mongu district has a very high iron content hence the water resources are prone to iron contamination. Several boreholes were decommissioned and abandoned in the district as the water was no longer portable due to high iron concentration exacerbating the impacts of climate change on water accessibility and availability. One of the key informants attributed the increase in iron concentration to the climate change induced drought which has lowered ground water levels leading to decreased dilution.

5.3.2 Risks associated with climate change impacts on water resources

The study found that the risks being experienced because of climate change impacts on water resources are loss of crops, loss of livestock, drinking contaminated water, water shortages, hunger and starvation, diseases, reduced fishing activities and human wildlife conflict. The researcher also tried to assess the severity of the risks being faced because of climate change impacts on water resources by asking them to state the risk that has been the most severe. The summary of results is presented in figure 3.

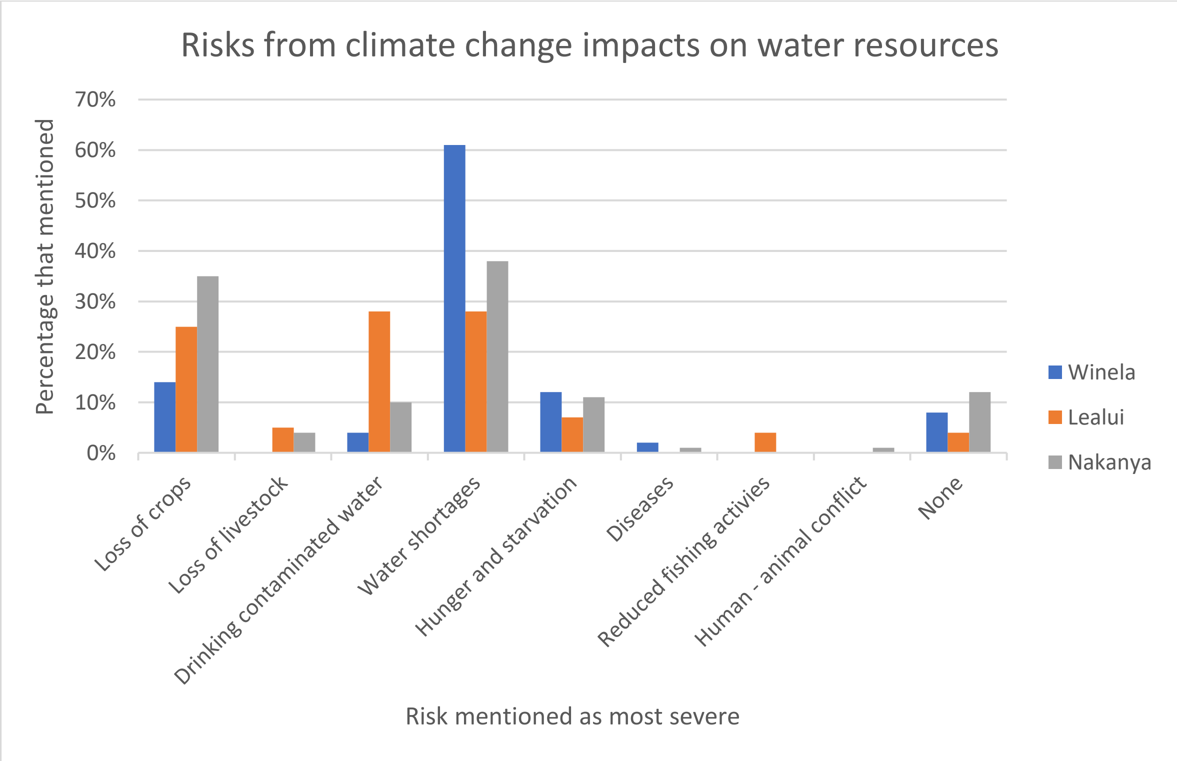

Figure 3: A summary of the risks considered as most severe by the respondents

Source: Field Data, 2024

5.4 Adaptation Strategies to the impacts of climate change on water resources

To reduce the negative impacts of climate change on water resources, different stakeholders have adopted various approaches, and these strategies primarily focuses on securing alternative sources of water in the face of drought.

5.4.1 Adaptation strategies by rural communities of Mongu District to the impacts of climate change on water resources

Rural communities have come up with survival strategies during times of low water availability and accessibility. The following are the adaptation strategies being utilized by rural communities to ensure survival during these times of droughts. As shown in table 4 the most dominant adaptation strategies were digging of more wells and deepening of existing wells (30%), moving long distances looking for alternative water sources (24%) and limiting water usage (20%). It was also noted that adaptation strategies vary between villages. For example, storage of water in drums, buying of water from neighbours and sinking of personal boreholes were unique to Malengwa village. Shifting from upper land to lower land was being practiced in Nakanya village. Boiling drinking water was only recorded in Lealui village. However, looking for alternative water sources and limiting water usage was being practiced across all the sampled villages.

Table 4 Adaptation strategies against climate change impacts on water supply

Adaptation Strategies	**Effectiveness of the adaptation strategies**	**Malengwa** **n=49**	**Lealui** **n=75**	**Nakanya** **n=81**	**Total** **n=205**	**Reason for Rating**
Digging more wells and deepening the existing wells	Minimally effective		43% (32)	36% (29)	30% (61)	They don't have resources to very deep wells. Water levels have reduced hence it is difficult to access the water. The wells end up collapsing because of the sandy nature of the area
Moving long distances to look for alternative water sources	Minimally effective	14% (7)	43% (32)	15% (12)	25% (49)	The strategy is time-consuming and physically demanding. Hence, it is difficult to find water that can meet their needs.
Limiting water usage	Not effective	31% (15)	5% (4)	27% (22)	20% (41)	The available water is insufficient to meet their demands
Buying water from neighbours with boreholes	Very effective but not sustainable because of the low-income levels of the rural communities.	31% (15)			7% (15)	Boreholes are a reliable source of water and since they are privately owned, access is limited, thereby reducing demand on the water supply.
Planting of trees	Not effective		5% (4)	12% (10)	7% (14)	Low survival rate of the planted trees.
Storage of water in drums and containers	Moderately effective	18% (9)			4% (9)	This strategy depends on the availability and

						accessibility of the water resources.
Shifting from upper land to lower land	Not effective			10% (8)	4% (8)	It is not possible for every household along with all its members to shift.
Sinking personal boreholes	Very effective, however only a few can afford.	6% (3)			2% (5)	Boreholes are a reliable source of water and since they are privately owned, access is limited, thereby reducing demand on the water supply.
Boiling water before drinking	Effective in minimising diarrhea and other related illnesses.		4% (3)		1% (3)	Effective in mitigating diarrhea and associated illnesses, however accessing firewood for boiling the water is becoming increasingly difficult.

Source: Field Data, 2024

5.4.2 Adaptation strategies by the local authorities

The following are the interventions being done by the local authorities to help improve the rural communities' resilience to climate change and its impacts on water resources.

- There have been efforts to increase water supply by drilling more boreholes as it has been noted that the existing water infrastructure is inadequate to meet the needs of the communities. For example, in Nakanya village which was one of the study sites the researcher found out that there are only two boreholes that have been drilled under the Constituency Development Fund (CDF). Hence, the local authorities are in the process of identifying more sites for borehole drilling. According to the Mongu IDP about 200 exploratory boreholes and 100 solar powered water schemes are to be constructed across the district. One key informant stated that increasing water availability and accessibility is critical in spreading the risk of climate change amongst the water resources, hence reducing stress on the water resources and increasing their resilience to climate change and its impacts. The key informant also mentioned that when drilling the boreholes there is need for the boreholes to be put in productive areas as he said that some of the boreholes have dried not because of climate change but because they were put in the wrong position without sufficient water resources.
- Construction of water supply mini schemes in the rural communities is one of the strategies being implemented by the local water authorities. According to the IDP for Mongu district there were about 45 water supply schemes that had been developed across the district so far. The key informant from the department of water supply and sanitation mentioned that they are in the process of transitioning from providing point water supply to piped water supply in the rural communities. However, he said that the piped water supply system can only be implemented in bigger clustered villages not in villages where the households are interspersed. They key informant also mentioned that there has been poor management and maintenance of the water schemes being established in the rural communities. This is because the local authorities cannot implement commercial water supply in rural areas, hence the schemes are managed and maintained by the communities, and it is on a voluntary basis.
- In addition to borehole drilling there have been efforts to also identify sites for dam construction. So far two (2) dam sites have been identified in the district with more sites yet to be identified.

- As a response to the decrease in water levels of underground water, borehole pumps are being lowered to reach the water level and ensure continued water supply in the face of climate change induced droughts.
- Food relief programs are another adaptation measure being employed by the government to support vulnerable households during times of drought. This strategy involves providing food assistance to households that are struggling to access sufficient food due to drought.

5.4.3 Adaptation options to enhance the rural communities' resilience to climate change impacts on rural water supply.

Through the key informant interviews and the household survey the researcher explored adaptation options that can enhance the rural communities' resilience against climate change impacts on water resources. The adaptation options that were mentioned by the sampled households as having the capacity to enhance their resilience against climate change impacts on water resources are summarized in figure 4. The findings indicate that the highest proportion of the respondents feel that drilling more boreholes in their communities will help reduce the adverse effects of climate change on rural water supply. This was followed by the introduction of irrigation systems, solar powered water pumps, hand pumps, introduction of drought resistant crops, planting of trees and increasing climate change awareness and early weather forecast system.

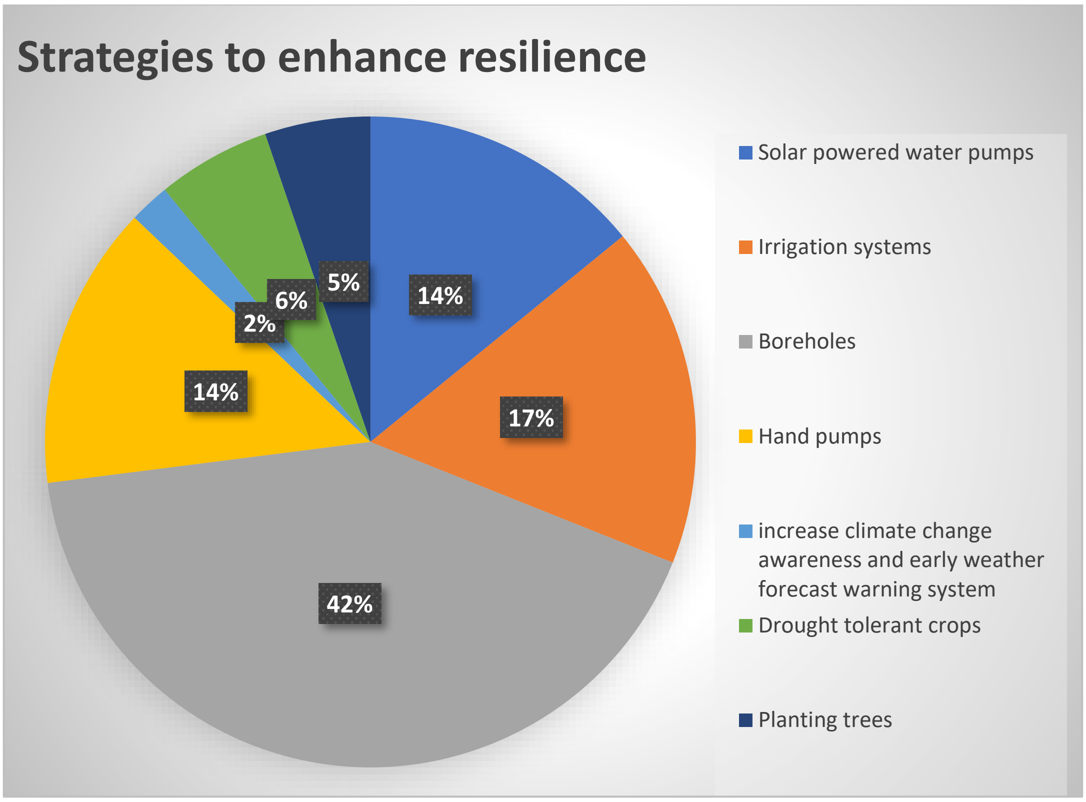

Figure 4: Adaptation strategies that were identified by the communities to have the capacity to enhance their resilience

Source: Field Data, 2024

The strategies that were mentioned by the key informants as having the capacity to enhance the rural communities' resilience against climate change impacts on water resources are:

- Household clustering
- Recharge mapping
- Riverbank filtration
- Reforestation and revegetation
- Water harvesting
- Deep drilling

CHAPTER SIX

DISCUSSION

6.1 Introduction

This chapter discusses the findings of the study presented in chapter five relating them to the study objectives.

6.2 Social vulnerability

The results of the study revealed that there are disparities in the vulnerability of rural households to climate change impacts on water resources across the three sampled villages. Nakanya village exhibited the highest vulnerability, with a social vulnerability index (SVI) value of 0.52, indicating a greater susceptibility to the adverse effects of climate change on water resources. In comparison, Lealui village recorded an SVI value of 0.45, while Malengwa village showed the lowest vulnerability, with an SVI value of 0.39. The variation in social vulnerability among the sampled villages can be attributed to their geographic location, with Nakanya village being the most marginalized and least developed, thereby exacerbating its social vulnerability. This is in line with the findings of Sahoo and Sridevi, (2021) who found that the overall social vulnerability to climate change of the less developed village was higher than the developed village. Another study by Pandey *et al*., (2015) found that the rural communities (less developed) were more vulnerable to climate change impacts on water resources than the urban areas (more developed).

Marginalised communities are often characterized by limited access to resources, less economic opportunities and insufficient or poorly maintained infrastructure. These factors increase their exposure and sensitivity to the impacts of climate change whilst limiting their capacity to adapt. For example, the results of the study show highest dependence on natural water sources that are sensitive to climate change and its impacts in Nakanya village because of insufficient infrastructure. On the other hand, Malengwa village is located just after the urban area of Mongu district and is characterized by better access to resources and economic opportunities, and low dependence on natural water sources. This reduces their exposure and sensitivity to the impacts of climate whilst increasing their adaptive capacity. Finally, Lealui village exhibits a moderate level of marginalization, which is relatively lower compared to Nakanya village. This lower marginalization, coupled with better access to resources, infrastructure, and economic opportunities, contributes to Lealui village's reduced vulnerability to climate change impacts on water resources.

6.3 Social Vulnerability Influencing Factors

In terms of the social vulnerability factors economic factors largely influenced high vulnerability in the three sampled villages. Dumenu and Takam Tiamgne, (2020) states that "income levels of households or individuals influences vulnerability as high-income level provides economic security and stability; hence, the ability to draw on alternative entitlements and access resources in the face of shock which in turn enhances their resilience".

Low-income communities often lack adequate infrastructure and have low access to clean, safe and reliable water exacerbating the impacts of climate change on water supply. Also contributing to the high economic indices is the dependence on climate sensitive occupation. Solely depending on climate sensitive occupation like crop production and fishing increases household's social vulnerability to the impacts of climate change as it compromises their livelihood especially in times of low crop or fish production (Dumenu and Takam Tiamgne, 2020). This is because any unfavourable change in environmental conditions caused by climate change negatively impacts production thus, by affecting the amount of food produced and sold for the well-being of the household (Sahoo and Sridevi, 2021). Diversified sources of income help improve household's adaptive capacity in the time of crisis as it provides insurance against shocks minimising exposure to the negative impacts of climate change because livelihood is derived from different income sources (Dumenu and Takam Tiamgne, 2020).

Malengwa village had the least climate sensitive occupation index of 0.06. This is because it had the lowest percentage of respondents that solely depend on crop production or fishing for their survival. Malengwa village is the closest to Mongu central business district (CBD) and the residents are involved in other economic activities like retail, piece jobs, welding and brick making. This diversity in income levels enhance their resilience against climate change impacts. Despite having a high-income level index of 0.88 the low climate sensitive occupation index of 0.06 reduced the economic factor index to 0.47 indicating reduced economic vulnerability as compared to Lealui and Nakanya villages that have economic factor indices of 0.66 and 0.69 respectively. On the other hand, Lealui and Nakanya villages had climate sensitive occupation index of 0.41 and 0.40 respectively. This shows high dependence on climate sensitive occupation like farming and fishing in the two villages. The high dependence on climate sensitive occupation is mainly because of the low economic activity in Lealui and Nakanya village as they are located far from the CBD.

Social factors had indices of 0.64 for Nakanya village, 0.45 for Lealui village and 0.44 for Malengwa village. These social factor index values indicate significant differences among the three villages with Nakanya village having the highest level of social vulnerability. This is because Nakanya village had the highest index value of 0.64 for social factors. The critical indicators that contributed to the highest index score for social factors in Nakanya village were lack of a reliable source of water (0.78), low ownership of radio or television (0.77), very weak social networks (0.77) and high dependence on natural water sources (0.68). In comparison Lealui and Malengwa had the following indices values respectively; reliable source of water (0.32; 0.65), ownership of a TV or radio (0.49; 0.49), social networks (0.63; 0.53) and dependence on natural water sources (0.36; 0). In addition to the above-mentioned indicators, access to community benefits and access to climate change information also influenced the social vulnerability. The index values for access to community benefits were 0.72 for Nakanya village and 0.8 for both Malengwa and Lealui villages. Access to climate change information had relatively low index values of 0.14 for Malengwa village, 0.09 for Leului village and 0.11 for Nakanya village.

The highest index value for reliable source of water in Nakanya village means that Nakanya village has the highest percentage of the residents that face significant challenges in accessing water for domestic use or to support their livelihoods. These challenges are being exacerbated by climate change showing high vulnerability of the households in Nakanya village to the impacts of climate change on water resources. Lealui village had the lowest index value of 0.32 for reliable source of water. This means that Lealui village has the lowest percentage of residents that have challenges accessing water for domestic use or to support their livelihoods. This maybe because of the geological and hydrological characteristics of Lealui village as it is located along the Barotse floodplains. Floodplains normally have a higher water table than sandy areas which are highly permeable and allows water to drain quickly. This helps increase water accessibility in Lealui village as compared to Nakanya and Malengwa villages that are dominated by sandy soils.

The low ownership of radios or televisions in Nakanya village indicates limited access to climate change information, which further exacerbate their vulnerability. TVs and radios are important means of disseminating information on climate change, early warning and adaptation strategies (Dumenu and Takam Tiamgne, 2020). Early warning system is considered as a technological measure that improves rural households' adaptive capacity to climate change and its impacts. Nakanya village had a TV or radio ownership index of 0.77 as compared to 0.49 in both Lealui and Malengwa villages. This means that Nakanya village had the lowest percentage of households that owned these important media gadgets.

The weak social networks imply lack of community cohesion and support making households not have access to social support. This makes them more vulnerable to climate change and its impacts. Social networks can result in improved collective action allowing communities to work together to address common challenges and build resilience. Nakanya village had the weakest social networks indicated by an index value of 0.77 followed by Lealui village with 0.63 and finally Malengwa with an index value of 0.53.

Dependence on natural water sources like streams and shallow wells increase communities' social vulnerability to the impacts of climate change on water supply. This is because these water sources are highly sensitive to climate change and increases the communities' exposure to climate change. In addition, depending on natural water sources means that communities' have limited control over the water supply increasing their vulnerability to the impacts of climate change. Nakanya village had the highest percentage of people that solely depend on natural water sources for domestic use. The index value for dependence on natural water sources for Nakanya village was 0.68 followed by Lealui with 0.36. Malengwa village had an index value of 0 for dependence on natural water sources. This means that of none of the sampled households solely depends on natural water sources. Malengwa village is more developed with better water infrastructure than Nakanya and Lealui village as it is closer to urban area of Mongu district. The major sources of water for households in Malengwa village were community taps, community tanks and boreholes, whilst in Lealui village they fetched water from hand pumps, shallow wells and rivers. In Nakanya village the major source of water were hand pumps and shallow wells. In addition, households in Malengwa village have higher levels of income and some of the households can afford to drill their personal boreholes. Those without boreholes can also afford to buy water from neighbours that have got boreholes if they cannot access water from the community taps.

Access to community benefits helps reduce households' social vulnerability to climate change and its impacts. Community benefits provide a buffer against the impacts of climate change helping households cope with the adverse impacts thus enhancing resilience. However, the high index values in all three villages means that a very small percentage of the households have access to community benefits. This increases the communities' social vulnerability to climate change and its impacts. Malengwa and Lealui villages had the same index value of 0.8. In contrast, Nakanya village had a slightly lower index value 0.72 meaning that a higher percentage in Nakanya village have access to community benefits.

On the other hand, access to climate change information had relatively lowest index values across all three villages. Lealui village had an index value of from 0.09 followed by Nakanya village with an index value of 0.11 and finally Malengwa village with an index value of 0.14. This means that in the three villages high percentage of households have access to climate change information. Access to climate change information reduces social vulnerability. According to Dumenu and Takam Tiamgne, (2020) access to climate change information is critical to developing appropriate and effective response to climate change impacts and enhance resilience.

Demographic factors recorded the lowest index value among the three social vulnerability factors across the three villages. This indicates that demographic factors had the least influence on high social vulnerability. Malengwa village recorded a demographic factor index of 0.26, with Nakanya village recording 0.25 and Lealui village 0.23.

All the three districts showed high literacy levels as 92% household heads in Malengwa village, 94 % in Nakanya village and 97% in Lealui village reported to have obtained at least primary level education. Households having education below the primary level are more vulnerable to climate change than households with above primary education (Sahoo and Sridevi, 2021) as literate people tend to better understand information and acknowledge risk (Dumenu and Takam Tiamgne, 2020). Therefore, the high literacy level across the three villages helps reduce their overall vulnerability.

Concerning household size, Nakanya village had the highest index value of 0.45. This means that Nakanya village had the highest average household size followed by Lealui village with and index of 0.34 and finally Malengwa village with 0.22. Household size plays a critical role in influencing the overall social vulnerability of a household as larger households are more vulnerable to the impacts of climate change. This is because larger households tend to channel most of their resources towards the welfare of household members leaving them with little to no resources to adapt to climate change impacts.

In terms of household leadership Malengwa village had the highest percentage of female headed households. This is indicated by the highest index value of 0.47 followed by Lealui village with an index value of 0.33 and finally Nakanya village with an index value of 0.23. Sam *et al*., (2017) states that female headed households are more vulnerable to impacts of natural hazards like climate change because of poor overall literacy rates and lack of networking ability among the women. In addition, female headed households tend to have limited access to resources which can limit their capacity to adapt to climate change and its impacts.

6.4 Risks associated with climatic hazards affecting rural water supply.

Based on the responses that were recorded the effects of climate change being experienced in the Barotse floodplains are an increase in the frequency of drought, increase in temperatures, changes in rainfall patterns, lack of rainfall, floods, and heavy winds. A study by Nyamwanza, (2018) found that climate change is being manifested through increasing intra-seasonal dry spells, increasing drought cycles and floods. The findings of this study are also inline with Banda *et al*., (2015) who found that communities around the Barotse Floodplains have started experiencing the negative impacts of climate change which include increase in atmospheric temperature and excessive heat in the plains, floods, prolonged dry spells, reduction in precipitation, unexpected changes in seasons and their durations and reduction in water supply. Other studies conducted in the Zambezi River Basin in which the Barotse floodplains lies have predicted rising temperatures, decreasing precipitation, extended drought periods and severe floods (Hamududu and Ngoma, 2020; Ndhlovu and Woyessa, 2021). These effects are already being experienced in the communities around the Barotse floodplains.

Despite the many climatic hazards being experienced in the Barotse floodplains, drought and excessively high temperatures are considered the most severe by a larger percentage of the population. This is because of the drastic effects drought and excessively high temperatures have had on the rural water supply, agricultural production, livestock production, fish production and the overall well-being of the communities. The climate change induced drought and extreme temperatures have reduced water availability and water accessibility as some of the of the streams, wells, and boreholes where communities used to get water from had dried up. As a result, people mostly women and children must move long distances and spend more time searching for water.

These findings agree with Mudombi and Muchie, (2013) who found that in Murewa and Seke districts in Zimbabwe the current climate variability has a marked impact on rural people's access to water with decreased rainfall being ranked as one of the most important factors impacting water availability. Another study by Abedin *et al*., (2014) in Khulna and Sutkhira districts of Bangladesh also found that drought was one of the major causes of water scarcity. As a result, women walked for long distances from one village to the other to meet the household's daily water needs. Another study by Rankoana, (2020) also found that drought, increased temperatures and low rainfall led to an inconsistent water supply for household consumption because of excessive water evaporation from the river. Consequentially the residents of the rural communities in Limpopo province travel a distance to fetch water from public sources. According to Kumar, (2016) climate change and water supply system are closely connected as it affects the hydrologic cycle by influencing precipitation, evapotranspiration, and soil moisture. Niang *et al*., (2014) also state that many studies in Africa point to a future decrease in water abundance due to a range of drivers and stresses that include climate change, a phenomenon already being experienced in the Barotse floodplains.

In addition, climate change has had drastic effects on agricultural production which is the main source of livelihood for the rural households. Loss of crops and livestock have been recorded as some of the risks being faced as result of climate change impacts on water resources. Rural communities in the Barotse depend on rainfed agriculture which is highly sensitive to climate change and variability. The climate change induced drought has severely impacted crop yields, causing crops like maize, rice, and cassava to dry out in the fields and resulting in little to no harvest. This has led to high food insecurity as majority of households are struggling to access adequate food resulting in hunger and starvation. A study by Nyamwanza, (2018) found that water for agricultural and domestic purposes was becoming scarcer. In addition, the study also noted there has been an increase in drought frequency over the years and these droughts have led to total crop failure, drying up of rivers and boreholes and livestock deaths (Nyamwanza, 2018). However, the drying of cassava which was reported by some of the respondents is different from the findings of Mupakati and Tanyanyiwa, (2017) where cassava was actually introduced in Chilonga ward in Chiredzi Zimbabwe as an adaptation option to cope with drought and climate change as it is considered a drought resistant crop.

Unavailability of water and grazing land has reduced livestock production as households can no longer keep livestock for food or for sale. There has also been an increase in cattle deaths and diseases because of climate change. These findings are in line with some of the findings by Rankoana, (2020) who reported that some of the participants mentioned that raising of livestock is curtailed due to a drop in the river water level because of drought. Nyamwanza, (2018) also found out that livestock deaths were one of the negative impacts of the climate change induced drought.

Drying of water bodies and lowering of water levels have also led to fish resources depletion resulting in reduced fishing activities which is a major source of livelihood for some of the households. These findings are in line with Milupi *et al*., (2019) who found that the major impacts of climate change being experienced in the Barotse floodplains were; low food production due to drought, reduction in cattle population due to excessive heat, lack of animal pastures due to drought, depletion of some fish species and reduction or low yields in crop harvest like maize and rice amongst others. This is supported by Abedin *et al*., (2014) who state that in the rural communities fisheries and livestock-based livelihoods are curtailed due to lack of safe water.

The impacts of climate change induced drought on water resources have had a negative effect on the people's health in the rural communities of the Barotse floodplains. This is supported by Mani *et al*., (2024) who states that drought has claimed the lives of 23,374 people in Sub Saharan Africa between 2000 and 2023 because of prolonged water scarcity, food insecurity, and related health crises. In addition, because of water scarcity people end up fetching water from unsafe sources like contaminated wells and there have been cases of diarrhoea and other related illnesses in the district. This is supported by Huang *et al*., (2021) who states that in times of reduced water quantity and quality people living in rural communities may have to use alternate sources with poor quality due to unavailability of safe water resources and high cost of water purification techniques. Dehydration is another health issue that is being experienced by the residents because of the reduced water supply. This is because some households are finding it hard to access clean water for drinking. In addition, when they find the water, they are trying to limit water usage, and this include reducing amount of drinking water. Impacts of climate change on water resources have also led to poor hygiene being practiced by the local communities as they are struggling to access water for hygiene practices like handwashing. Some residents said that they can go for days without taking a bath. A study by Buriro *et al*., (2024) found that rising temperatures are contributing to an increase in heat-related illnesses, such as heatstroke, while erratic rainfall patterns and droughts are exacerbating water shortages, leading to poor sanitation and the spread of waterborne diseases like cholera and diarrhea in Sindh Pakistan.

6.4 Adaptation strategies to the impacts of climate change on rural water supply

To reduce the negative impacts of climate change on water resources, different stakeholders have adopted various approaches. The specific adaptation strategies of individuals, communities, and institutions such as local authorities, NGOs, and private sector all play a critical role because together they can potentially reduce adverse effects of climate change on rural water supply in an area (Abedin *et al*., 2014). The study found that the strategies being implemented were digging and deepening of wells, travelling longer distances to fetch water, limiting water usage, buying water, storing water in drums, borehole drilling, construction of water supply mini schemes, lowering of borehole pumps and identification of dam sites.

Adaptation strategies being implemented by the sampled households are primarily focused on securing alternative sources of water, reducing water consumption, and improving water storage. On the other hand, strategies being implemented by institutions such as the department of water and the western water and sewerage company aim at increasing water availability and accessibility in the face of climate change. The adaptation measures being implemented by the communities and institutions are explained below.

Digging and deepening of wells: It is one of the primary strategies being used by the rural communities to increase water availability and accessibility in times of drought. This strategy is employed to increase access to groundwater, which is often more reliable than surface water during times of drought. By deepening existing wells or digging new ones, households can tap into deeper aquifers, reducing their vulnerability to drought. This practice is considered to be unsustainable by Macdonald *et al*., (2009) who states that those who still rely on unprotected shallow wells and ponds are likely to become increasingly insecure.

Travelling longer distances to fetch water: Since local water sources have depleted, household members are travelling to neighbouring villages to access water from water sources that haven't dried. However, this strategy is time-consuming and physically demanding, particularly for women and children who are bearing the responsibility of fetching water. Some people said they wake up as early as 4am to look for water and others were complaining of muscle aches because of fetching water. This practice was also reported by Mudombi and Muchie, (2013) and Rankoana, (2020).

Limiting water usage: This strategy involves reducing water consumption for non-essential activities. Some of the respondents said that they are even going for a week without taking a bath. By limiting water usage, households are helping reduce their water demand and help conserve the water resources. This practice is in line with the findings of Rankoana, (2020) whereby the residents of Maheni community have laid down restrictions on water uses during increasing water stress periods to ensure a sustainable water supply.

Buying water from neighbours with boreholes: This strategy involves purchasing water from neighbouring households that have access to more reliable water sources, such as boreholes. This strategy is common in Malengwa village which has highest levels of income. Because of the higher income levels some of the residents in Malengwa can afford to drill their personal boreholes. In addition, the other residents can also afford to buy the water. However, this strategy can be unsustainable, particularly for households that lack the financial resources to purchase the water. This strategy was also reported by Patrick, (2021)who found that respondents in Mkhanyakude District in South Africa were making personal arrangements such as buying water from water vendors to ensure water security within their households when faced with diminishing water resources.

Storage of water in drums and containers: In Malengwa village some of the households have resorted to storing water in drums and containers when they manage to access the water. This practice is in line with the findings of Rankoana, (2020) whereby some of the residents of Maheni community stated that they collect and store water as it becomes available from the borehole. However, one of the key informants said that this practice is unsustainable as it increases the pressure on the water sources making them more vulnerable to climate change. When households fetch and store excessive amounts of water, it can lead to over-extraction of water and can reduce the availability of water for other users and can also lead to the depletion of water resources. Instead, he encouraged households to fetch the amount of water that is sufficient for their daily needs and consumption.

Shifting from upper land to lower land: Some of the residents of Nakanya village are now relocating to lower-lying areas that are more likely to have access to reliable water sources. By shifting to lower land, households can improve their access to water and reduce their vulnerability to drought. Shifting from lower land to upper land and vice versa is a common practice and is considered a cultural heritage amongst the Lozi people. Annually they hold the Kuomboka ceremony which is an annual relocation of people, their cattle and the Litunga from the plains to the upper land (Milupi *et al*., 2019).

Borehole drilling: Borehole drilling is one of the primary adaptation measures employed by local institutions. This strategy involves drilling boreholes in strategic locations to provide reliable access to groundwater for rural communities. By drilling boreholes, institutions can improve access to water for rural households and reduce their vulnerability to drought. Macdonald *et al*., (2009) recommended that boreholes should be located in the most productive parts of the aquifer and also suggested that tests be carried out to assess the performance of a well or borehole, once it has been constructed, providing valuable information on how the source will behave during drought. They go on to suggest that if a single source cannot meet peak dry season or drought demand, further sources should be developed.

Construction of water supply mini schemes The institutions are also constructing small-scale water supply systems, such as piped water systems in villages to provide reliable access to water for rural communities. By constructing water supply mini-schemes, institutions can improve access to water for rural households and reduce their vulnerability to drought. However, the key informants stated that the water schemes can only be implemented in clustered villages not in villages where the households are interspersed. However, there has been poor management and maintenance of the water schemes being established in the rural communities. This is because the local authorities cannot implement commercial water supply in rural areas, hence the schemes are managed and maintained by the communities, and it is on a voluntary basis. This is in line with Huang *et al*., (2021) who states that many rural communities have inadequate facilities for water acquisition, storage, distribution, and protection as most of these facilities may not be up-to-date or cannot keep up with the increasing water demand, and many rural facilities are aging and gradually losing efficacy due to a lack of repair and maintenance.

Identification of dam sites: There have been efforts to identify suitable locations for dam construction to provide reliable access to water for rural communities. By constructing dams, institutions can improve access to water for rural households and reduce their vulnerability to drought. Construction of dams is supported by Ryan and Elsner, (2016), whose study indicated that sand dams have potential to increase adaptive capacity and resilience to climate change in drylands. However, the key informants stated that it is difficult to find good dam sites in the Western Province because of the geological characteristics of the area.

Lowering of borehole pumps: It has been noted that the ground water levels have reduced hence the lowering of pumps by the institutions in existing boreholes to increase access to groundwater. By lowering borehole pumps, institutions can improve access to water for rural households and reduce their vulnerability to drought. A study by Kulkarni *et al*., (2021) revealed that drilling deeper wells helps to sustain water yields as it increases borehole volume because the well's storage ability for percolating water is improved in deeper wells.

Food relief: Food relief programs are another adaptation measure employed by the government to support vulnerable households during times of drought. This strategy involves providing food assistance to households that are struggling to access sufficient food due to drought. By providing food relief, the government can help to reduce the hunger and starvation that resulted from the drought.

6.5 Adaptation options to enhance the rural communities' resilience to climate change impacts on rural water supply

Introduction of irrigation schemes: 17% of the respondents mentioned that irrigation schemes can help enhance their resilience to climate change impacts on water supply. This is because crop loss, hunger and starvation were reported as some of the risks being faced as a result of climate change impacts on water supply. Sahoo and Sridevi, (2021) states that improved irrigation facilities are the most important adaptation strategy to alleviate the negative impacts of climate change in the face of erratic and untimely rainfall. Irrigation strategy helps in increasing the agricultural yield because people will have access to water even in the eventuality of water shortage and less rainfall (Sahoo and Sridevi, 2021). In addition, Macdonald *et al*., (2009) state that smallholder agricultural systems with groundwater-based smallholder irrigation are an important intervention for increasing agricultural production, leading to strengthened agricultural livelihoods and reduced poverty in Africa.

Introduction of drought resistant crops: Growing of drought resistant crops was considered a crucial strategy in adapting to climate change impacts on water resources by some of the respondents. Drought resistant crops like sorghum and millet require less water to grow and can ensure productivity even under drought conditions. This can help minimise the hunger and starvation that is being experienced as a result of frequent climate change induced droughts in the Barotse floodplains.

Household clustering: The key informants recommended clustering of homesteads in the rural communities to improve water accessibility in the face of climate change. Rural communities are often characterized by isolated homes that are scattered across the landscape with significant distance between them, and high dependence on natural water supplies that are vulnerable to climate change. Hence the efforts by the local authorities to drill boreholes which are resilient to the impacts of climate change in response to the prevailing climatic conditions. However, the key informants emphasized that it is not possible to drill boreholes anywhere people settle as some of the places are not suitable for borehole drilling. Therefore, clustering households and drilling boreholes at designated points will help improve access to water resources in the face of climate change. The key informants also mentioned that clustering households makes it possible to implement the piped water supply or reticulation system instead of the point water supply currently being implemented in rural communities thereby improving water accessibility.

Recharge mapping: The key informants also mentioned that there is need to identify and map areas where groundwater recharge can be enhanced or restored. The key informant from the Western Water and Sewerage Company particularly stated that when conducting feasibility studies for borehole drilling it is not enough to just identify the site for borehole drilling but there is need to identify the recharge point for the aquifer from which the borehole will be tapping water from. He went on to say that identifying the recharge zones ensures that they are well maintained. There has been an increase in the frequency and intensity of drought in the region which has led to a decrease in groundwater levels. Therefore, recharge mapping will help maximize groundwater recharge and ensure sustainable groundwater management. This is supported by Macdonald *et al*., (2009) who in an effort to promote drought proofing of rural water supplies recommended exploring methods of increasing groundwater recharge and reducing evapotranspiration like the use of managed aquifer recharge to enhance recharge.

Riverbank filtration: The key informant from Western Water and Sewerage Company strongly recommended riverbank filtration as one of the adaptation measures that will ensure communities' resilience against the impacts of climate change on water resources. He stated that Boreholes can be drilled at strategic positions along the Zambezi River and its tributaries where they will be intercepting the aquifer that is recharged by the river water. He went on to say that the western water and sewerage company have drilled boreholes along Kambule stream, and these boreholes have not been affected by the prevailing drought conditions whilst some of the boreholes they have drilled away from the stream have dried showing the potential of riverbank filtration in increasing resilience of water supply systems to climate change. The key informant also stated that the water from riverbank filtration is free from iron and sediments as the riverbank filtration is a natural water treatment process that filters and purifies water using soil and sediments along the riverbank. According to Umar *et al*., (2017) integrating riverbank filtration and aquifer recharge and recovery system are some of these techniques and can provides a lasting solution to water scarcity especially in arid and semi-arid climates. Riverbank filtration can be used in drought-prone regions as a means of increasing water-storage capacity. According to Osman *et al*., (2022) riverbank filtration has been used for over 150 years in Europe to produce large quantities of drinking and industrial water at low cost and high quality, even during floods and droughts.

Reforestation and Revegetation: Incorporating reforestation and revegetation into adaptation strategies can also enhance the resilience of water resources to climate change and its impacts. The key informant from the western water and sewerage company stated that there is need to discourage the cutting down of trees in certain areas, especially for charcoal production as this has a negative impact on water resources. This is because vegetation promotes water infiltration and retention, and reduction of moisture-stress during low rainfall by increasing soil porosity and soil cover reducing surface runoff (Pramova *et al*., 2012). In Brazil, recovery of riparian forest areas around water bodies is one of the main strategies being used for water conservation as increasing forest areas, helps to improve hydrological conditions in hydrographic basins (Freitas *et al*., 2022).

Rainwater harvesting: One of the key informants from the department of water resources development mentioned that there is need to implement effective water harvesting systems, especially during floods whereby the excess water will be collected and stored for future use. This can enhance water security and reduce climate change induced water scarcity. This practice is supported by Huang *et al*., (2021) who states that rainwater harvesting is listed among the specific adaptation measures which can be employed to cope with future climate change and its impacts on rural communities, particularly in regions of Africa. A study was conducted in Central Northern Namibia to investigate the application of rainwater harvesting and it was found that rainwater harvesting in terms of the roof catchment systems was economically feasible and could provide comparable benefits to public water supply (Huang *et al*., 2021).

Deep drilling: The key informants stated that to enhance water accessibility in the face of decreased water levels from the climate change induced drought deep drilling can be implemented. This will involve drilling boreholes to depth of about 200m or more. This practice is supported by Issar and Adar, (2010) who states that the negative impact of global warming can be mitigated by using the groundwater resources stored from past wetter times through deep drilling, pumping and modern irrigation methods. A study by Kulkarni *et al*., (2021) revealed that drilling deeper wells helps to sustain water yields as it increases borehole volume because the well's storage ability for percolating water is improved in deeper wells.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

This chapter concludes the study and outlines the recommendations based on the research findings.

7.2 Conclusion

This study assessed the susceptibility of rural communities in the Barotse Floodplains catchment to climatic hazards affecting rural water supply. It also explored adaptation options for ensuring sustainable rural water supply in the face of climate change.

From the findings of the study, it can be concluded that socioeconomic factors along with geographical location influence the social vulnerability of rural communities in the study area. These factors reduces their capacity to adapt to the impacts of climate change on water supply. It was noted that marginal communities are more vulnerable to the impacts of climate change than centrally located communities that have better access to resources. It was noted that lack of adequate water infrastructure greatly increases the adverse effects of climate change rural water supply hence increasing the communities' social vulnerability. The rural communities in the Barotse floodplains have inadequate infrastructure which exacerbates the challenges they face as they adapt to the impacts of climate change on water supply.

Drought has been noted as the most prominent cause of accelerated water scarcity in the rural communities as it reduces water accessibility as well as availability. The drought induced water scarcity has led to adverse effects like water shortages, drinking contaminated water and loss of crops and livestock. To reduce the negative impacts of climate change on water resources, different stakeholders have adopted various approaches, and these strategies primarily focuses on securing alternative sources of water in the face of drought. However, the current adaptation strategies being implemented are insufficient given the magnitude of the changes currently taking place highlighting the need for more effective strategies. The findings of the study reveal that development of climate change resilient infrastructure is critical in enhancing the rural communities' resilience against the impacts of climate change on water supply systems. From the results of the study, it can also be concluded that having multiple sources of water is important in spreading the risk of climate change amongst the several sources as compared to having one source. The study's results also highlight the need for a multi-faceted approach to climate change adaptation, one that involves the active participation of various stakeholders, including households, communities, and institutions.

7.3 Recommendations

1. To enhance climate change resilience, this study recommends that the department of water resources development and department of water supply and sanitation prioritize investments in the design, construction, and maintenance of climate-resilient water infrastructure that can withstand current and projected climate change impacts. Examples include rainwater harvesting systems, solar powered boreholes, dams and reservoirs, and protected wells.
2. The study recommends development of community-based water management systems by the department of water supply and sanitation. Under this approach, community-based water committees have responsibility for the operation and maintenance of water supply systems including hardware repairs and equipment upgrade. Research has found that a successful and sustainable water resource management strategy requires the aid of knowledge, opinions, and experience from local communities who would be the key stakeholders in resource conservation.
3. To enhance the resilience of rural communities to climate change and reduce their social vulnerability, this study recommends that government and non-government institutions support initiatives that promote diversified livelihoods, focusing on climate-resilient income sources that are less sensitive to climate variability. Examples include creating and selling handicrafts, engaging in small scale manufacturing activities like detergent making, candle production and tailoring.

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Appendices

Appendix A: Household survey – Semi-structured interview

Questionnaire for local people in the rural communities of the Barotse floodplains on their vulnerability to climate change impacts on rural water supply and the adaptation strategies they are implementing to cope with negative impacts.

Dear respondent,
My name is Everjoy Mhereyenyoka a second-year master's student at the University of Zambia in the School of Natural Sciences pursuing a Master of Science in Environmental and Natural Resources Management in the department of Geography and Environmental Studies. I am conducting a study to assess the social vulnerability and adaptation strategies that are being implemented by the people from the Barotse floodplain in response to the impacts of climate change on water resources.

You are kindly requested to answer the questions in this questionnaire. Your participation in this survey is voluntary. This research is purely academic, and any information gathered in this survey will only be used for the purposes of research. Please respond as honestly as you can to all the questions. Feel free to make further comments you may want to. The interview is completely confidential, and your name will not be recorded in this Questionnaire.

Name of the Numerator: ……………………………………………………………………..

Name of Village: ....

Date of Survey: ....

Questionnaire No: ....

SECTION A: Household information

1. Gender of the respondent
    a. Male
    b. Female
2. Age
3. Are you the household head?

4. If no to the above question, who is the household head?

5. How many people live in your household?

6. Can you please list the age and gender of the people that live in your household.

7. What is the highest level of education that was completed by the household head?
    a. Never been to school
    b. Primary education
    c. Secondary education
    d. Tertiary education

8. What are your sources of income as a household?

9. What is the average monthly income for the household?

10. In times of need do you receive help from friends, relatives or community leadership?

11. Do you have access to community projects, benefits, and aid in times of crisis?

12. Have you ever heard about climate change?

13. Do you own a TV or a radio?
    a. Yes
    b. No

14. Where do you get water for use from?

15. What is the distance to the water source?
    a. Less than 1km
    b. 1-3 km
    c. More than 3km
16. Is the water always available?

17. On a scale of 1 to 5, how can you rate the quality of the source of water for the household? (1 very poor, 5 very good)
    a. Very poor
    b. Poor
    c. Average
    d. Good
    e. Very good

SECTION B: Risks associated with climate change impacts on water supplies

18. Are there any extreme weather events you have been facing because of climate change? If yes, please state.

19. Which of the extreme weather events has been most severe? Explain the reason for your answer.

20. How has climate change affected the water supply in your area?

21. What risks have you faced because of climate change impacts on water resources?

22. Which of the risks has been most severe? Explain the reason for your answer.

SECTION C: Adaptation to the impacts

23. Can you describe the strategies your household has implemented to cope with climate change impacts on water supply?

24. Are there any initiatives being done at community level to address the challenges being faced? If yes, please describe.

25. On a scale of 1 to 5 how do you consider the effectiveness of the existing strategies in addressing the impacts of climate change on the water supply in your community? (1 Not effective, 5 very effective)
    a. Not effective
    b. Minimally effective
    c. Moderately effective
    d. Highly effective
    e. Very effective

26. Has your community received any external support (e.g. from government or NGO's) to help improve water supply and adapt to climate change? If yes, please describe.

27. What other measures do you think can be put in place to address the impacts of climate change on the water supply in your community?

28. What measures have you put in place to counter the risks that have resulted from the impacts of climate change on water supply?

29. How effective have been these measures in minimizing the risks?

Thank you for your participation

APPENDIX B: Key informant interview guide.

Dear respondent,

My name is Everjoy Mhereyenyoka a second-year master's student at the University of Zambia in the School of Natural Sciences pursuing a Master of Science in Environmental and Natural Resources Management in the department of Geography and Environmental Studies. I am conducting a study to assess the social vulnerability and adaptation strategies that are being implemented by the people from the Barotse floodplain in response to the impacts of climate change on water resources.

You have been selected by virtue of position. You are therefore, kindly requested to answer the questions in this questionnaire. Your participation in this survey is voluntary. This research is purely academic, and any information gathered in this survey will only be used for the purposes of research. Please respond as honestly as you can to all the questions. Feel free to make further comments you may want to. The interview is completely confidential, and your name will not be recorded in this Questionnaire.

Name of the Numerator: …………………………………………………………………………..

Date of Survey: ....

1. What are the main climate-related hazards that have impacted rural water supply in the upper Zambezi River basin in recent years?

2. How have these climate-related hazards affected the availability, quality, and accessibility of water resources for rural communities?

3. What changes have you observed in the frequency, intensity, or timing of these climate-related hazards over time?

4. What are your projections or concerns about how future climate change may impact rural water supply and in the region?

5. What adaptation strategies (indigenous knowledge, community-based initiatives, and technological interventions) are currently being employed by the communities to address the impacts of climate change induced tipping points on water resources?

6. How effective are the identified adaptation strategies in ensuring a sustainable water supply in the face of climate change?

7. What implications do these strategies have on the environment and society?

8. Do these adaptation options have the potential for long-term sustainability and scalability?

9. Are there any interventions that have been done by the local or national government, NGOs, or other organizations to help the communities address the impacts of climate change on water resources?

10. How successful were the interventions in improving the communities' adaptive capacity to the impacts of climate change on water resources?

11. What other adaptation options can be implemented by the communities in response to the climate induced tipping points affecting rural water supplies?

12. What can be done to reduce the communities' vulnerability to the impacts of climate change and enhance their resilience?

13. What technological, social, or financial innovations could enhance the climate resilience of rural water supply in the region?

14. Is there anything else you would like to share regarding the social vulnerability and adaptation strategies of rural communities in the Upper Zambezi River catchment?

THANK YOU FOR YOUR PARTICIPATION.

APPENDIX C. ETHICAL CLEARANCE

THE UNIVERSITY OF ZAMBIA

DIRECTORATE OF RESEARCH AND GRADUATE STUDIES

Great East Road Campus | P.O. Box 32379 | Lusaka10101 | Tel: +260-211-290 258/291 777 **Fax**: (+260)-211-290 258/253 952 | **E-mail**: director.drgs@unza.zm | Website: www.unza.zm

APPROVAL OF STUDY

IORG No. 0005376

HSSREC IRB No. 00006465

REF NO. NASREC: 2024-FEB-017

5th April, 2024

Ms. Everjoy Mhereyenyoka

The University of Zambia

P.O. Box 32379

LUSAKA

Dear Ms. Mhereyenyoka

RE: "SOCIAL VULNERABILITIES AND ADAPTION OPTIONS TO CLIMATE INDUCED TIPPING POINTS AFFECTING RURAL WATER SUPPLIES IN THE UPPER ZAMBEZI RIVER CATCHMENT".

Reference is made to your protocol dated as captioned above. 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-2024-FEB - 017**
Approval and Expiry Date	Approval Date: 5th April 2024	Expiry Date: 4th April, 2025
Protocol Version and Date	Version - Nil.	4th April, 2025
Information Sheet, Consent Forms and Dates	English.	To be provided
Consent form ID and Date	Version - Nil	To be provided
Recruitment Materials	Nil	Nil
Other Study Documents	Questionnaire.	

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. NASREC 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

VICE-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