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# Climate Change and its implications on the Barotse Floodplain in Western Province Zambia

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**Abstract:** *The Barotse Floodplain, a vast wetland area in Zambia, is facing severe impacts from climate change. The primary objective of the study was to provide a comprehensive understanding of the impact of climate change on the Barotse Floodplain and develop sustainable and effective strategies for adaptation. The research aim was to investigate the various impacts of climate change on the ecosystem, hydrological impacts, ecological dynamics, socio-economic repercussions, and indigenous potential adaptation strategies. This was a mixed method study utilizing both qualitative and quantitative methods. To gather quantitative data, eight (8) water samples were conveniently collected from eight (8) informal settlements within the Barotse Floodplain area, namely Lyeneno, Likundu, Lyatolo, Liyala, Indoo, Little Zambezi River, Zambezi River and KB1 from the main city of Mongu. The collected sterilized and recommended water collection bottles underwent various analysis from bacteriological test to pH tests measured by the Western Water & Sewerage company in Mongu. For qualitative data, eight (8) semi-structured interviews were purposively administered to the community leaders from each informal settlement where the water samples were collected. This study found that the water quality in the Barotse floodplain was negatively impacted by climate change but were within acceptable WHO limits. The social-economic impacts have the potential to harm the surrounding ecosystem and the livelihoods of the local communities. The study recommends the urgent need for action to address the impacts of climate change on the Barotse Floodplain and other vulnerable ecosystems around in western province.*

**Keywords:** *Climate change, Barotse floodplains, informal settlements, water quality, adaptation, ecosystem.*

## 1. INTRODUCTION

### 1.1. Climate Change in Zambia

Climate change is a pressing global issue that demands immediate attention and action (IPCC, 2022). Its far-reaching consequences are becoming increasingly evident, posing significant challenges to the stability and well-being of nations around the world, including Zambia (Thurlow *et al*., 2012). The changes are projected to result into seasonal droughts, dry periods within the rainy season, intense rainfall, heat waves, increased temperatures, flash floods and changes in growing season as a result of delayed onset of rainy season or shortened growing periods (Lusajo *et al*., 2017). Moreover, the urgency of climate change in Zambia cannot be overstated as changing rainfall patterns, prolonged droughts have disrupted agricultural productivity and resulting into food insecurity and increased poverty levels. This has also been found in the Barotse Floodplain area, which serves as the study area of this research. Floodplains are among the earth's most dynamic and productive ecosystems. They are 'areas that are periodically inundated by the lateral overflow of rivers or lakes and/or by direct precipitation or groundwater. The surface of the plain alternates between terrestrial and aquatic environments. They serve as vital habitats for diverse plant and animal species, provide valuable ecosystem services, and support human populations through crops and water resources (Bayley, 1995). However, floodplains around the world are increasingly experiencing the profound impacts of climate change, which is changing their natural hydrological regimes and ecological dynamics (Mitchell, 2013). The Barotse Floodplain in Western Zambia experiences four distinct seasons. The rainy season, known as *Litabula*, lasts from October to April, with the wettest months being December and January. The flood season, called Munda, occurs from February to May, with humidity dropping after March and skies beginning to clear. The winter season, known as *Maliha*, lasts from May to August, with warm days and cold nights, and the possibility of frost in August. The hot, pre-rainy season, called *Mbumbi*, occurs from September to November, with very hot days and occasional thunderstorms. Flooding usually begins in December when the Zambezi River's discharge increases, resulting in an overflow into the flood plain, and peaks in April (Flint, 2007, Chileshe *et al* 2024).

Among the many pressing issues in Zambia is climate change. This issue has affected socio economic development of not only the Barotseland but the country as a whole (MLNREP, 2016). This is for the reason that the nation is at present experiencing climate induced menaces, which include flash floods dry spell as well as life-threatening temperatures (MLNREP, 2016). The effect of climate change in Zambia extend to biodiversity as well as the fauna and flora (Oxfam, 2015). For instance, flora such as vegetation which hitherto redeveloped rapidly have been dawdling to recuperate due to the high temperature and drought effects of climate change (Milupi *et al.*, 2019). The change in climate is already affecting people in the rural areas (Oxfam, 2015). For instance, heat, drought and floods are increasing in the rate of recurrence. Crops are destroyed by droughts and because of such and may other effects, climate change has led it being introduced in the development policies in Zambia such as national development strategies (Milupi *et al*., 2019).

However, the climate in the Barotse Floodplains has been changing in recent years, and the area has been adversely affected by the impact of climate change. The region is experiencing increasing unpredictability and extremes in temperature, rainfall patterns, and flooding as well as El Niño events (Flint, 2007). Hotter temperatures during the hot-dry season and colder temperatures in mid-winter have led to a sharp decline in agricultural production, ultimately resulting in famine in the communities. Additionally, the more frequent damaging storms, with high winds and heavy rains, have caused significant damage to infrastructure and homes, posing a threat to the safety and well-being of people and unusually high floods are damaging crops and infrastructure. Climate change has also resulted in water scarcity, which is likely to increase in the future. temperatures in mid-winter have led to a sharp decline in agricultural production, ultimately resulting in famine in the communities. Additionally, the more frequent damaging storms, with high winds and heavy rains, have caused significant damage to infrastructure and homes, posing a threat to the safety and well-being of people and unusually high floods are damaging crops and infrastructure. Climate change has also resulted in water scarcity, which is likely to increase in the future.

### 1.2. Aim of the study

The primary objective of the study is to provide a comprehensive understanding of the impact of climate change on the Barotse Floodplain area and develop sustainable and effective strategies for adaptation. The research aims to examine the various impacts of climate change on the ecosystem, including hydrological impacts and indigenous potential adaptation strategies. By conducting a thorough analysis of these factors, the study aims to promote a nuanced and detailed understanding of the complex relationship between climate change and the Barotse Floodplain area. The research seeks to enhance our understanding of how climatic shifts affect this critical wetland area, enabling informed decision-making for sustainable resource management, resilience-building, and effective policy formulation in the face of evolving environmental challenges. The study aims to identify strategies that can be most effectively employed to mitigate the profound consequences of climate change in this particularly vulnerable region. Ultimately, the goal of the research is to develop a comprehensive framework for addressing the impacts of climate change on the Barotse Floodplain area and promoting sustainable development in the region.

### 1.3. Research Objectives

1. Identify the impacts of climate change in the Barotse Floodplain Area
2. Investigate the water quality in Barotse Floodplain Area
3. Investigate indigenous potential adaptation strategies in Barotse Flood Plains Area

## 2. DESCRIPTION OF THE STUDY AREA

### 2.1. General Information

The study was conducted in the Western Province of Zambia in the Barotse Floodplain. The Barotse Floodplain, also known as the Bulozi Plain, Lyondo, or Zambezi floodplain (Milupi et al., 2019), is a vast wetland located in the upper Zambezi River Basin in the Western Province of Zambia, Southern Africa (Zimba et al., 2018). It borders Angola to the west and Namibia to the southern part, making it an important region for trade and commerce. The floodplain is a result of the Zambezi River re-entering Zambia from Angola, and it is in the upper reaches of the Zambezi River. The floodplain area is a vast ecological system that spans approximately 5500 km2, with a maximum flooded area of around 10,750 km2 with a total population of approximately 250,000 people in the Western Province of Zambia, Southern Africa. It is a relatively flat, annually flooded plain that stretches from Lukulu to Senanga, covering approximately 230 km and a width of about 50 km, making it the second-largest wetland in Zambia. Its coordinates are 15°40′0″S and 24°10′0″ E or −15.6667 and 23.1667 in decimal degrees. The elevation of the Barotse Floodplain ranges from 1192m above sea level in the North Eastern part at Mitete and Lukulu to 900m above sea level at Senanga and Sioma (Banda et al., 2022). The area supports a diverse array of flora and fauna, including fish, bird, and reptile species, making it a crucial habitat for the region's biodiversity. Peak water levels in the Barotse Floodplain occur in April and are decreasing from May to July (Milupi et al., 2019). During November, when water levels are at their lowest, the region still contains many lagoons, swamps, and channels. The floodplain plays a crucial role in the hydrology of the Zambezi River, which supports the livelihoods of millions of people in the region. This study has specifically targeted communities in the eastern part of the Floodplains near Mongu town, which serves as the headquarters of Western Province. The names of the villages investigated are namely, Lyeneno, Likundu, Lyatolo, Little Zambezi, Liyalaa and Indoo.

### 2.2. Geographical Features

The geographical features of the Barotse Floodplain area are characterized by the Zambezi River, diverse soil conditions and a very distinctive vegetation. The Zambezi River, extending approximately 2,700 km from its source to the ocean, ranks as the fourth longest river in Africa, is the source of the floodings in the Barotse Floodplain (Flint, 2007). The floodplains in the region are periodically submerged by lateral river or lake overflow, as well as direct precipitation or groundwater, leading to a dynamic alternation between terrestrial and aquatic environments. The soil fertility within the floodplain is characterized by a wide variability, with different soil types present. The floodplain's soil composition includes Kalahari sands, originating from Upper Karoo sandstones. These sands are moderately acidic, low in fertility, and contain 3 to 12 percent silt and clay. The floods play a vital role in depositing essential nutrients onto these nutrient-deficient soils (Banda et al., 2022). Other areas, such as the Sishanjo or Litongo gardens, provide year-round cultivable land, but overuse has led to topsoil removal in the area. This region is a crucial producer of fish and cattle in southern Africa (Flint, 2007).

The floodplain's vegetation includes both evergreen and semi-evergreen swamp and riparian woodlands, as well as Kalahari and Munga Woodland. Surrounding the floodplain, the upland areas are covered by low canopy woodland vegetation like Brachystegia or Mopane, accompanied by diminishing hardwoods like Rhodesian teak and rosewood (Flint, 2007). In the western regions, woodland transitions into vast savannah grassland plains, notably within the Liuwa National Park. In these upland areas dambos and pans are found, which is where cultivation takes place on clay outcrops, showcasing the unique interplay of geographical features in the Barotse Floodplain area. Primary land uses in the area involve cropland cultivation, cattle grazing, and timber production (Banda et al., 2022).

### 2.3. Socio-Economic Feature

The Barotse floodplain area is inhabited by the Lozi people and holds a rich socio-economic significance: Starting from the 16th century, the Luyi migrated to the Barotse Floodplain, finding a land capable of sustaining them despite annual flooding. From the 17th to the 20th century, the Lozi established a powerful political economy based on their cultivated food surpluses and innovative survival strategies (Neeta, 2016). The socio-ecological functioning of the plain, the river, the kingship, and the unique Lozi culture have all played critical roles in holding the system together. The Barotse Floodplain area is thus of tremendous significance to the Lozi people, providing them with a profound sense of identity that has been passed down through generations (Flint, 2007). Agriculturally, the floodplain supports cultivation of vegetables like tomatoes, cabbages, and leafy greens, while upland areas yield maize, sorghum, and cassava. Understanding flooding dynamics is crucial for seasonal crop planning. Recession farming follows the flood period, with proper timing vital for successful harvests (Mapedza, 2022).

Economically, the region relies on small-scale trade involving fish, cattle, agricultural produce, aquatic plants, and forestry goods. Limited modern industries and low-income levels prevail, except for the timber industry. Despite this, the area holds potential for tourism due to its strategic location, floodplains, biodiversity, and cultural events like the annual "Kuomboka" ceremony (Flint, 2006).

The selection of the Barotse Floodplain as the research area of this study was driven by its exceptional vulnerability to the impacts of climate change. Neeta (2016) goes as far as stating that “the Barotse floodplain is one of the most vulnerable physical environments in Zambia”. In addition, the variety of crops such as bulrush millet, maize, cassava, sweet potatoes, pulses, fruit trees, sugar cane, tobacco, and vegetables all year round equally necessitated the selection of are as a research area as this can economically boost the economy of Barotse land as well as the nation (Milupi et al, 2024).

The region's climate has become increasingly variable and unpredictable, with changes in rainfall patterns and extreme weather events such as droughts and floods becoming more frequent. As a result, the livelihoods of the people who live in the area have been affected, and their ability to adapt to these changes is crucial (Flint, 2007). Therefore, the overarching goal is to identify strategies that can be most effectively employed to mitigate the profound consequences of climate change in this particularly vulnerable region.

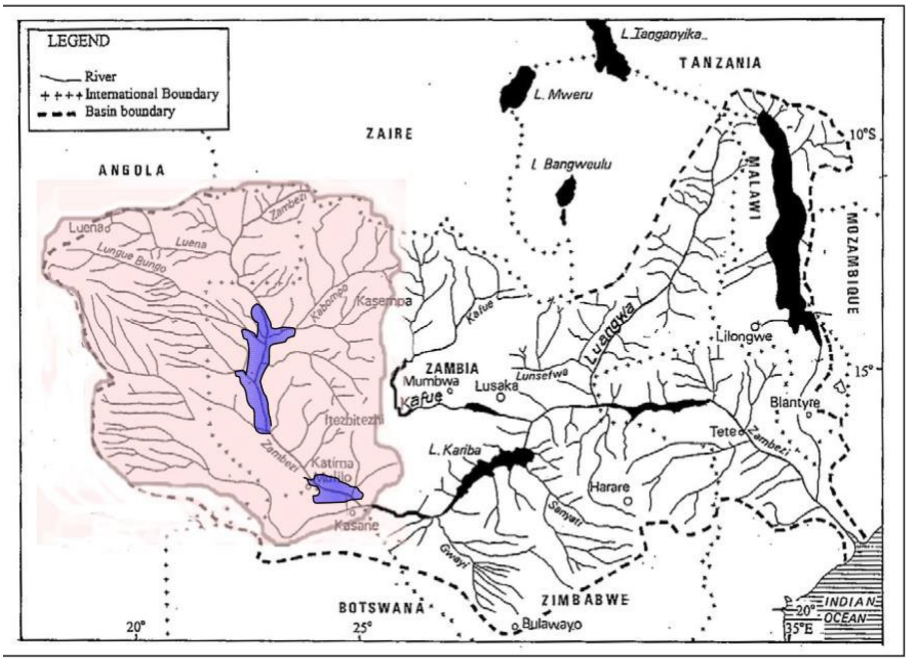


**Figure1.** *Map of the Barotse Floodplains, Source: Flint, 2007*

## 3. METHODS AND MATERIALS

### 3.1. Research Design

This chapter outlines the methodology used in this study to assess the impact of climate change on the Barotse Floodplain area, including the research design, sampling technique, data collection tools and data analysis. This was a mixed method study utilizing both qualitative and quantitative methods. The research design for this study includes a quantitative approach and interviews with community leaders on environmental information. To collect data on water quality, sampling was conducted in 8 villages within the Barotse Floodplain area, including Lyeneno, Likundu, Lyatolo, Liyala, Indoo, Zambezi, Little Zambezi as well as in Mongu town. A total of 8 water samples were collected, with an equal distribution of four taken from surface water sources and four from boreholes. The samples were collected in designated areas in a clean and efficient manner to ensure sample credibility and purity. Furthermore, the location and time of sample collection were also recorded to provide context for the samples.

### 3.2. Data Collection and Data Analysis

To collect this information, they utilized GPS devices to record the coordinates of each water sample they collected. Additionally, the team interviewed local community leaders about social economic impacts. Due to language barriers, an interpreter helped to translate the interview questions into Lozi. It is important to note that the researchers-maintained research ethics throughout the data collection process. Western Water provided the necessary data for the analysis of the quality of drinking water from their labs. The data was then collectively integrated into an excel sheet, allowing for a more organized and comprehensive analysis of the information. Together with the information from the informants, graphs and tables were used which allowed for a more in-depth and visual presentation of the data analysis, yielding key insights and trends that might have otherwise gone unnoticed. WarpPLS software was used to analyze water quality results to identify and model non-linearity among variables in path models. Qualitative data were analysed using emerging themes from the collected information. The analysis of the quantitative data also helped to make well-informed conclusions.

## 4. Findings and Discussions

### 4.1. Water quality results

This chapter includes the results of water quality tests conducted on various water sources within the area, as well as the findings from interviews with community leaders. The data collected and analysed provides a comprehensive understanding of the impact of climate change on the region and its inhabitants. The results of the quality of water tests can be found in the following table 1 below:

**Table1.** *Water quality results, source: Western Water Company*

| Parameter/ Village | Source of water | pH | Turbidy (NTU) | Color | Calcium (Ca) | Iron (Fe) | Total Solids (TDS) | Chlorides (Cl) | Sulphate (SO4) | Floride (F) |
|---|---|---|---|---|---|---|---|---|---|---|
| **WHO limit** | | 8.1 | 15.0 | 500.0 | 137.0 | 0.6 | 100.0 | 400.0 | 300.0 | 1.5 |
| **Lyeneno** | Surface | 7.0 | 0.3 | 34.0 | 11.2 | 0.1 | 36.9 | 8.8 | 1.0 | 0.4 |
| **Likundu** | Borehole | 6.9 | 52.5 | 715.0 | 12.9 | 0.4 | 75.3 | 5.0 | 2.0 | 0.0 |
| **Lyatolo** | Borehole | 5.7 | 0.0 | 34.0 | 7.6 | 0.1 | 40.7 | 15.5 | 83.0 | 1.5 |
| **Little Zambezi** | Surface | 6.7 | 0.0 | 27.0 | 9.3 | 0.1 | 42.0 | 13.6 | 52.0 | 0.3 |
| **Liyala** | Borehole | 5.8 | 12.1 | 71.0 | 12.9 | 0.6 | 868.0 | 181.0 | 0.0 | 0.9 |
| **Zambezi** | Surface | 6.9 | 0.0 | 20.0 | 9.0 | 0.1 | 31.9 | 5.4 | 53.0 | 0.2 |
| **Indoo** | Surface | 6.6 | 0.0 | 7.0 | 8.3 | 0.4 | 56.6 | 4.1 | 0.0 | 0.3 |
| **KB1** | Borehole | 7.9 | 0.0 | 14.0 | 8.3 | 0.0 | 31.2 | 15.0 | 1.0 | 0.0 |

The water quality test results in the study area reveal a range of values for key indicators of water safety. The pH levels of the samples ranged from 5.7 to 7.9, with the Lyeneno sample being slightly more acidic than the WHO limit of 8.1. While the pH levels of all samples were within acceptable limits, the Lyeneno sample was on the lower end of the range and may require further monitoring to ensure it remains safe for consumption. Turbidity levels are an important measure of the clarity of water and can impact its aesthetic qualities and safety. All samples in the study area had turbidity levels within the WHO limit of 15. This suggests that the water is relatively clear, indicating that it is less likely to contain suspended solids, sediments, or other organic materials that can pose health risks. Color, another measure of water quality, varied widely in the samples tested.

The Likundu sample had the highest value, at 715, while the Lyeneno sample had a color value of 34. High levels of color can indicate the presence of organic matter, such as decaying leaves or algae, which can make water unattractive and affect its taste. It is important to note that color does not necessarily indicate water safety; however, it can affect the water quality. Calcium levels in the samples ranged from 7.6 to 12.9, with the Likundu sample having the highest value. Calcium is an essential mineral that is required for healthy bones and teeth; however, high levels of calcium can cause hardness in water, which can lead to scaling in pipes and appliances. Iron levels in all samples were below the WHO limit of 137.5, indicating that the tested water is not contaminated with this mineral. The total dissolved solids (TDS) levels ranged from 31.2 to 868, with the Liyala sample having an unusually high value of 868 compared to the other samples, but still within the WHO limit of 1000. TDS measures the concentration of dissolved solids in water, such as minerals, salts, and metals. High TDS levels can affect the taste of water and may indicate the presence of other contaminants. Chlorides and sulphates were also present in varying amounts in the water samples. High levels of these minerals can lead to corrosion in pipes and appliances. Fluoride levels were all within the WHO limit of 1.5, except for the Liyala sample which had a value of 0.9.

Overall, the water quality test results indicate that there may be some issues with the safety and potability of the water in some of the locations tested since Liyala, Lyatolo, and Likundu had elevated levels of certain minerals and contaminants. While the samples were generally within acceptable limits, the study suggests that further monitoring and treatment may be necessary to ensure that the water is safe for consumption and meets acceptable standards. Figure 2 ,the water quality path model shows the results and identified non-linearity among variables in path models. The results confirms that Likundu is the only informal settlement which wasn't significant with a P-Value (P=0.25) > 0.05 compared to the WHO limits.

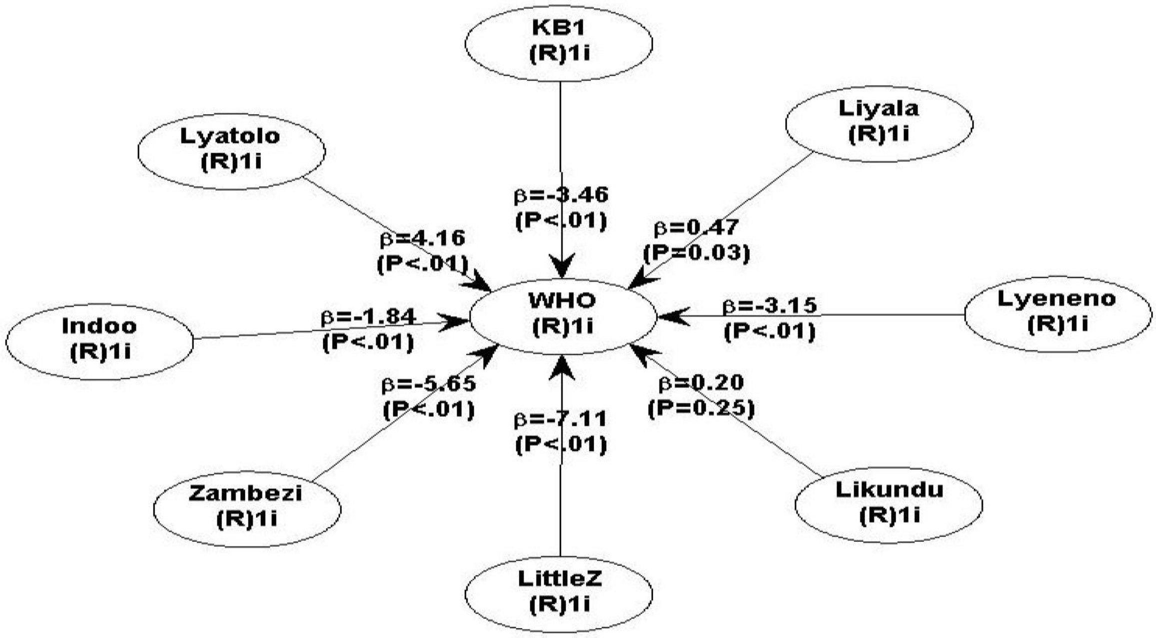


**Figure2.** *Water Quality Path Model*

## 4.2. Environmental Effects

The outcome of the interviews conducted on environmental information on the Barotse Floodplain area revealed that climate change is having a significant impact on the region. Specifically, 63% of the respondents indicated that they experience excessive effects of climate change, suggesting that the region is particularly vulnerable to the effects of climate change according to Figure 3.

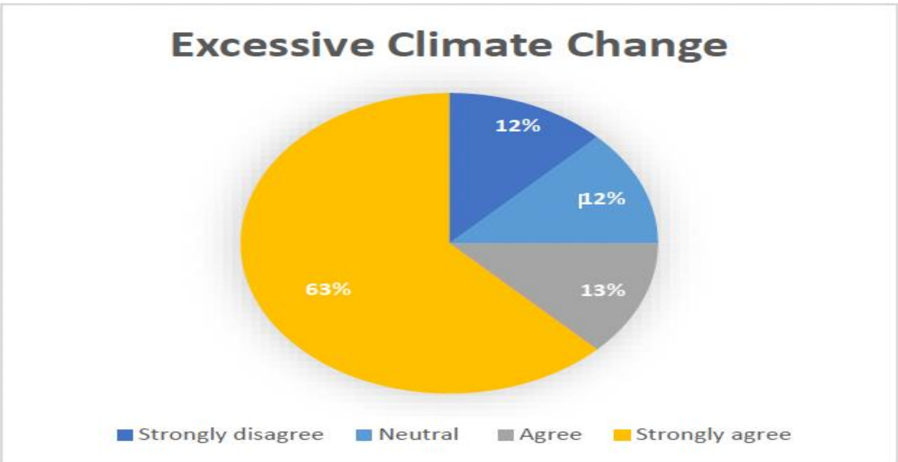


**Figure3.** *Effects of climate change*

Climate change and insufficient management of resources was suggested was agreed as the cause of significant decrease in the fish population in the waters of the Bartose Floodplain area according to figure 4. This statement was agreed on by some of the participants while others denied that statement to be true.

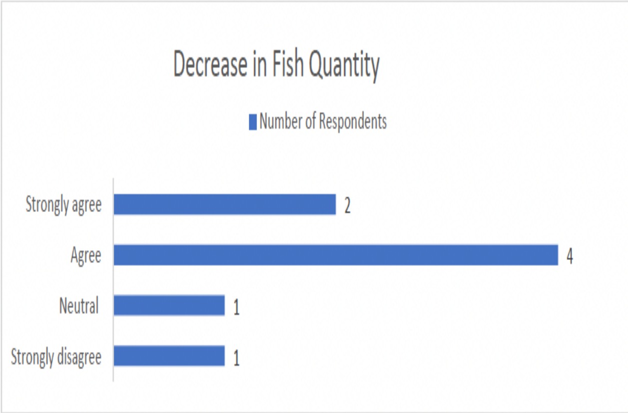


**Figure4.** *Decrease of fish quantity*

In addition to the other questions, the respondents were asked if they had experienced any waterborne diseases due to climate change. Waterborne diseases are illnesses caused by consuming or meeting contaminated water, including but not limited to Cholera, Typhoid, and Hepatitis. The responses to this question varied greatly, with some strongly agreeing and others strongly disagreeing. The specific results are shown in Figure 5.

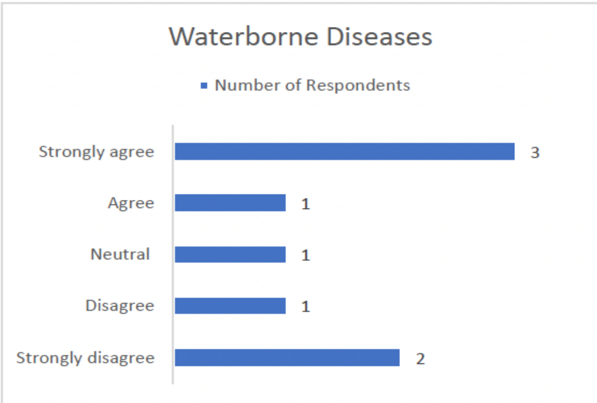


**Figure5.** *prevalence of water borne diseases*

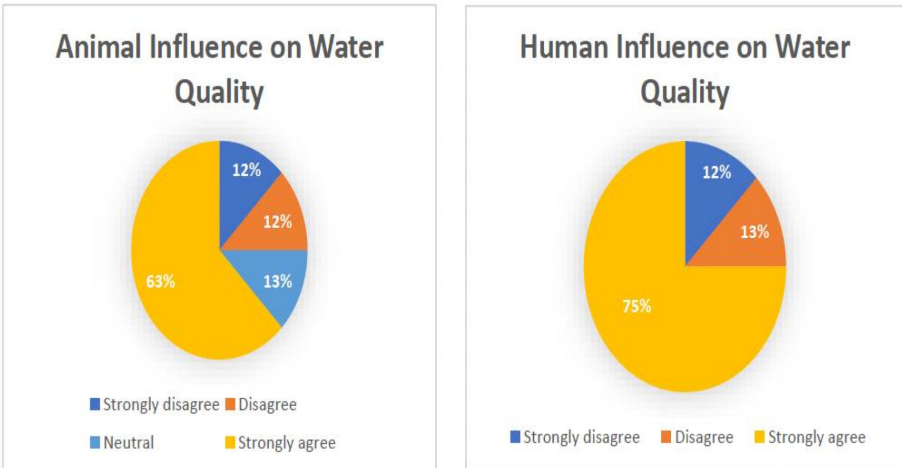


**Figure6.** *Human and Animal influence on water quality*

The existence of waterborne diseases indicates that the water in the studied communities is contaminated. To find out more about the source of the contamination, the interviewees were asked to indicate whether they believe that the water is contaminated through animal or human influence. Almost all respondents revealed that they strongly agree with that statement. According to figure 6, 63% respondents strongly agreed that there is animal influence on the water quality, while even 75% said that human activities influence the water quality.

The outcome of the interviews highlights the urgent need for effective strategies to address climate change and its implications on the Barotse Floodplain. The region's vulnerability to climate change underscores the importance of promoting sustainable and effective strategies for climate change adaptation that consider the social, economic, and environmental aspects of the region. The interviews provide valuable insights into the effects of climate change on the Barotse Floodplain area and underscores the need for urgent action to address these impacts.

## 5. Conclusion and Recommendations

### 5.1. Conclusion

The Barotse Floodplain, a vast wetland in Zambia, is facing severe impacts from climate change. The floodplain, which is home to a diverse range of flora and fauna, has experienced significant changes in its water quality because of climate change. This study has found that the water quality in the floodplain has been negatively impacted, which has the potential to harm the surrounding ecosystem and the livelihoods of the local communities that rely on it. In conclusion, the study highlights the urgent need for action to address the impacts of climate change on the Barotse Floodplain and other vulnerable ecosystems around the Zambia. There is need for Policy makers to encourage civic and community participation in policy formation and implementation needed (Kabaghe, 2017). The study provides valuable insights into the effects of climate change on the Barotse Floodplain area and underscores the need for immediate action to address these impacts.

### 5.2. Recommendations

Based on the findings of this study, several recommendations can be made:

- **Climate-Resilient Agriculture:** Agriculture extension services should promote the adoption of food-resistant crop varieties and innovative farming techniques that can withstand changing flood patterns. Providing training and information on adaptive practices can enhance local farmers' resilience.
- **Community-Based Flood Management:** Collaborative efforts between community members, local leaders, and relevant authorities are essential. Implementing early warning systems, floodplain zoning, and improved infrastructure can enhance the ability to manage flood events.
- **Diversification of Livelihood:** Encouraging the diversification of income sources beyond agriculture and fishing can reduce the vulnerability of households to climate-induced disruptions. Providing training and support for small-scale enterprises and off-farm employment can contribute to increased resilience.
- **Capacity Building and Education:** Promoting education and awareness campaigns on climate change impacts and adaptation strategies is crucial. Empowering communities with knowledge can help them make informed decisions and effectively respond to challenges.

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- Future aspirations under severe stress in rural Africa.
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