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THE IMPACT OF CLIMATE CHANGE ON WATER QUALITY IN RURAL COMMUNITIES: A CASE OF BINDURA DISTRICT

A dissertation submitted in partial fulfillment of the requirements for the degree of Honours in Science Education Geography

By

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DEDICATION

The research is dedicated to my entire family for their moral support and financial support for 2 years I have spent at the University

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ABSTRACT

This study investigates the impact of climate change on water quality in rural Bindura district, Zimbabwe. The research was motivated by the need to understand the effects of climate variability on water resources in rural communities, where access to clean water is already a challenge. The study employed a systematic approach, using questionnaires and observation guides to collect data from rural communities in Bindura district. The findings of the study reveal that high temperatures, changes in water levels, and lack of access to clean water are some of the significant impacts of climate change on water quality in rural Bindura district. The study also highlights the vulnerability of rural communities to climate change, who face significant challenges in accessing clean water for domestic use. However, the study also identifies adaptation strategies that can be employed to mitigate the impacts of climate change, including rainwater harvesting, dam construction, and the use of drought-tolerant crop varieties. The study also explores the role of indigenous knowledge systems in adapting to climate change, highlighting the importance of traditional knowledge and practices in enhancing community resilience. The findings of the study have significant implications for policy and practice, particularly in the areas of water resource management, climate change adaptation, and community development. The study concludes by making recommendations to residents, the educational sector, and NGOs on how to enhance community resilience to climate change. The study also identifies areas for further research, highlighting the need for continued investigation into the impacts of climate change on water quality and community livelihoods. Overall, this study contributes to a deeper understanding of the complex relationships between climate change, water quality, and community livelihoods in. rural Zimbabwe

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DECLARATION

I CHINGANGA LOVENESS RUVIMBO hereby declare that, except for references to other people's work which had been duly acknowledged, this dissertation is my original my own work which was never submitted in any other institution before.

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(Supervisor)

CHAPTER 1

THE PROBLEM AND ITS CONTEXT

1.1 Introduction to the study

Water quality is a critical component of rural water supply systems in Bindura, influencing community perceptions and potentially impacting the sustainability of these systems. The perceived poor quality of water can lead to the adoption of alternative, often unsafe, sources, thereby increasing the risk of water-borne health risks. Climate change is exacerbating this issue in Bindura, affecting water quality through rising temperatures, altered rainfall patterns, and increased sediment and nutrient inputs, which can result in decreased drinking water quality and eutrophication. This chapter aims to provide an overview of the study, including its background, purpose, statement of the problem, research objectives, research questions, scope, delimitation, and limitations. By exploring these key aspects, this chapter sets the stage for a comprehensive examination of the impact of climate change on water quality in Bindura, District.

1.2 Research Background

Climate change is one of the most pressing issues of our time, with far-reaching consequences for the environment, human health, and the economy (Moyo, 2014). One of the most significant impacts of climate change is on water quality, particularly in rural areas where access to clean water is already limited. Changes in temperature and precipitation patterns, increased frequency of extreme weather events, and rising sea levels are all affecting the quality of water, posing significant risks to human health and livelihoods, (Musarurwa and Lunga, 2012).

Also, the concern about climate change and water quality is growing rapidly, driven by increasing evidence of the impacts of climate change on water resources. Rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events are all contributing to this growing concern. For instance, increased temperatures are altering the chemical composition of water, leading to increased levels of pollutants and sediments. Moreover, changes in precipitation patterns are affecting the quality of water, with increased runoff and contamination of water sources during heavy rainfall events, (Nyathi, 2008).

Zimbabwe's freshwater resources, comprising a network of rivers, thousands of small dams, lakes, numerous wetlands, surface water and significant amounts of groundwater, are critical for supporting life, economic development and natural ecosystems. The deterioration in the quality of water resources is due to multi-sectoral factors that include discharges of untreated or partially treated wastewater from cities, towns and industries (Zambuko, 2007). Challenges posed by the discharge of untreated or partially treated wastewater from cities and towns can be traced to weak waste collection and management by local authorities. Most local authorities lack proper waste collection, disposal and management facilities that meet international standards. As a result, all urban local authorities, including growth points, dispose of solid waste at open dumps that have no linings to prevent leachates from contaminating surface and groundwater. In addition, the mining sector, which has been boosted by the recent discovery of large mineral deposits including diamonds, is a major contributor to point source pollution of water despite the existence of effluent standards and legislation against water pollution (IPCC, 2017).

According to, Jarawaza, (2010), the impacts of climate change on water quality are having significant consequences for human health, particularly in rural areas. Climate change is increasing the risk of water-borne diseases, such as cholera, typhoid, and dysentery. Moreover, rising temperatures are increasing the risk of heat stress, particularly for vulnerable populations such as the elderly and young children. Additionally, climate change is affecting agricultural productivity and food security, leading to increased risk of malnutrition, particularly in rural areas.

Also, the economic impacts of climate change on water quality are also significant, particularly in rural areas. Climate change is increasing the costs of water treatment, particularly in rural areas where water treatment infrastructure is limited. Moreover, climate change is increasing the costs of healthcare, particularly in rural areas where access to healthcare is limited. Additionally, climate change is affecting agricultural productivity and food security, leading to increased costs of agricultural production and reduced economic opportunities (Moyo, 2014).

Additionally, in Zimbabwe, the impacts of climate change on water quality are particularly pronounced. The country is experiencing increased temperatures, changing precipitation patterns, and increased frequency of droughts and floods (Ncube, 2010). These changes are affecting the quality of water, posing significant risks to human health and livelihoods. The Bindura District, in particular, is a rural area that is highly vulnerable to the impacts of climate change on water quality.

Apparently, Musana, is a rural area that is highly vulnerable to the impacts of climate change on water quality. The district is characterized by a semi-arid climate, with limited rainfall and high temperatures (Mugabe et al., 2018). The communities in Bindura rely heavily on rainwater harvesting and boreholes, which are often contaminated with pollutants and sediments (Mudyiwa et al., 2020).

Furthermore, climate change is affecting the quality of water in Bindura in several ways. Rising temperatures are altering the chemical composition of water, leading to increased levels of pollutants and sediments (WHO, 2019). Changes in precipitation patterns are affecting the quality of water, with increased runoff and contamination of water sources during heavy rainfall events (Mugabe et al., 2018). Moreover, the increased frequency of droughts and floods is placing additional pressure on already strained water resources (UNEP, 2019).

The impacts of climate change on water quality in Bindura are having significant consequences for human health and livelihoods. Climate change is increasing the risk of water-borne diseases, such as cholera, typhoid, and dysentery (WHO, 2019). Moreover, rising temperatures are increasing the risk of heat stress, particularly for vulnerable populations such as the elderly and young children (IPCC, 2020).

Additionally, climate change is affecting agricultural productivity and food security, leading to increased risk of malnutrition, particularly in rural areas (UNEP, 2019).

The communities in Bindura are highly vulnerable to the impacts of climate change on water quality due to limited access to clean water, sanitation, and hygiene facilities (Mudyiwa et al., 2020). Moreover, the district lacks adequate water treatment infrastructure, making it difficult to provide clean water to the communities (Mugabe et al., 2018). To adapt to these impacts, the communities in Bindura are using various strategies, such as rainwater harvesting and conservation agriculture (Mudyiwa et al., 2020).

Climate change is having a growing impact on the African continent, hitting the most vulnerable hardest, and contributing to food insecurity, population displacement and stress on water resources. In recent months we have seen devastating floods, an invasion of desert locusts and now face the looming spectre of drought because of a La Niña event. Science-based climate information is the foundation of resilience building, a cornerstone of climate change adaptation, as well as an oasis for sustainable livelihoods and development. The State of Climate Report for Africa has, therefore, a critical role to play in this respect, including in informing our actions for achieving the goals of the Africa Agenda 2063, Sacko, (2015)

In the Sahel region of Africa, lakes and dams are the vital source of water for millions of people in Chad, Nigeria, Cameroon, and Niger. However, the lakes are facing significant challenges due to climate change, which is affecting its water quality and availability (UNEP, 2019). Rising temperatures and changing precipitation patterns are altering the lake's hydrology, leading to increased evaporation and reduced water levels (IPCC, 2020).

The water levels of Lakes for instance Lake Chad have decreased significantly over the past few decades, from approximately 25,000 square kilometers in the 1960s to around 1,500 square kilometers today (CIESIN, 2019). This decrease in water levels has led to increased salinity, making the water less suitable for human consumption, agriculture, and livestock production (Mara, 2018). The increased salinity has also

affected the lake's biodiversity, with many aquatic species struggling to survive in the changing environment.

In addition, the impacts of climate change on Lake Chad's water quality and availability are having significant consequences for human health and livelihoods. The decreased water levels and increased salinity have reduced the availability of clean water for drinking, cooking, and hygiene, leading to increased risk of water-borne diseases (WHO, 2019). Moreover, the reduced water availability has affected agricultural productivity and food security, leading to increased risk of malnutrition and poverty (FAO, 2019).

Moreover, climate change's significant impacts on water quality in the Sahel region including rising temperatures and changing precipitation patterns are altering the region's hydrology, leading to increased evaporation, reduced groundwater recharge, and decreased water availability . Droughts and high inter-annual climate variability are exacerbating the Sahel's water scarcity issues, affecting both surface and groundwater quality . The increased frequency and Climate change is significantly impacting water quality in the Sahel region of Africa. Rising temperatures and changing precipitation patterns are altering the region's hydrology, leading to increased evaporation, reduced groundwater recharge, and decreased water availability (Zambuko, 2007).

In the words of Ndlovu, (2016) droughts and high inter-annual climate variability are exacerbating the Sahel's water scarcity issues, affecting both surface and groundwater quality . The increased frequency and severity of droughts and floods are also leading to the contamination of water sources, posing significant risks to human health and livelihoods . Furthermore, climate change is altering the distribution and prevalence of water-borne diseases in the Sahel region. Changes in temperature and precipitation patterns are creating ideal breeding conditions for disease-carrying insects, such as mosquitoes, which are vectors for diseases like malaria and cholera .

The Sahel region's vulnerability to climate change is compounded by its limited adaptive capacity, inadequate infrastructure, and existing development challenges. To address these challenges, it is essential to adopt a holistic approach that incorporates

climate change adaptation and mitigation strategies, improves water management practices, and enhances regional cooperation and knowledge sharing [1].
of droughts and floods are also leading to the contamination of water sources, posing significant risks to human health and livelihoods .

Furthermore, the distribution and prevalence of water-borne diseases has been altered in the Sahel region. Changes in temperature and precipitation patterns are creating ideal breeding conditions for disease-carrying insects, such as mosquitoes, which are vectors for diseases like malaria and cholera .The region's vulnerability to climate change is compounded by its limited adaptive capacity, inadequate infrastructure, and existing development challenges. To address these challenges, it is essential to adopt a holistic approach that incorporates climate change adaptation and mitigation strategies, improves water management practices, and enhances regional cooperation and knowledge sharing (IPCC, 2020).

The case study of Bindura highlights the significant impacts of climate change on water quality, human health, and livelihoods in rural areas of Zimbabwe. The district's vulnerability to climate change is exacerbated by limited access to clean water, sanitation, and hygiene facilities, as well as inadequate water treatment infrastructure. To address these impacts, it is essential to develop and implement effective adaptation strategies that prioritize the needs of rural communities.

1.3 Problem statement

According to Ncube, (2010), climate change has emerged as a significant threat to human health, economic development, and environmental sustainability worldwide. One of the most critical impacts of climate change is on water quality, particularly in rural communities where access to clean water is already limited. Bindura District in Zimbabwe is one such rural community that is vulnerable to climate change impacts on water quality. Rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events such as droughts and floods are altering the water cycle and affecting water quality in Bindura District. In an ideal situation, the

water supply system in Bindura, Zimbabwe, would provide clean, safe, and reliable water to all members of the community.

The current situation in Bindura, Zimbabwe, is characterized by a lack of access to safe and reliable water, particularly in rural areas. The water supply system is inadequate, with many communities relying on unprotected sources such as wells, rivers, and streams. These sources are often contaminated with bacteria, viruses, and parasites, which can cause a range of water-borne diseases, including cholera, typhoid, and diarrhea (Mara et al., 2018). Furthermore, the lack of adequate water treatment and sanitation infrastructure in the district increases the risk of waterborne diseases. This study's main question is: What are the impacts of climate change on water quality in rural communities?

1.5 Research Aim

The research aims to find out the impact of climate change on water quality in rural communities.

1.5.1 Research Objectives

1. To investigate the impacts of climate change on water quality in Bindura District.
2. To assess the vulnerability of rural communities in Bindura District to climate change impacts on water quality.
3. To assess other environmental and geological factors that contribute to water shortage in the area.
4. To identify effective adaptation strategies for improving water quality management in Bindura District.

1.5 Research questions

1. What are the impacts of climate change on water quality in Manhenga, Chireka and Nyava?

2. How does changes in temperature and precipitation patterns affect water quality in Bindura District?
3. Are there other environmental factors that contribute to the vulnerability of these rural communities in Bindura?
4. Which adaptation strategies can be used to manage water quality in Bindura District

1.7 Assumptions

The researcher assumes that participants will be willing to share their experiences, perceptions, and opinions about water quality and climate change, also that respondents will be willing to provide accurate and reliable data about their water use, perceptions of water quality, and experiences with climate-related events.

The relevant documents, records, and archival data will be available and accessible for analysis and that relevant datasets, such as climate data, water quality data, and demographic data, will be available and accessible for analysis.

Climate change is having a perceived impact on water quality and community livelihoods. Also, that climate change is having a measurable impact on water quality, as indicated by changes in water temperature, precipitation patterns, and other climate-related variables.

Community members have some level of awareness about the importance of water quality and the risks associated with poor water quality and the community members have a measurable level of knowledge about water quality and climate change, as indicated by survey responses or other quantitative measures.

The local government officials will be willing to provide access to relevant documents, records, and archival data and the officials will provide necessary permissions and approvals for data collection and will assist with data collection efforts.

Also, necessary resources, such as funding, equipment, and personnel, will be available to support data collection and analysis. Funding, equipment, and personnel, will be available to support survey design, data collection, and data analysis.

Qualitative research methods, such as interviews, focus groups, and document analysis, will provide valid and reliable insights into community perceptions and experiences. Surveys and statistical analysis, will provide valid and reliable measures of community knowledge, attitudes, and practices related to water quality and climate change.

1.8 The significance of the study

The significance of this study lies in its potential to contribute to the understanding of the impacts of climate change on water quality in rural communities. In Bindura climate change is a threat that requires immediate attention, and its impacts on water quality are far-reaching and devastating. Investigating the impacts of climate change on water quality in Bindura District, helps to provide valuable insights into the ways in which climate change is affecting rural communities in Zimbabwe (Tshuma &Mathuthu, 2014).

Apart from that, one of the most significant contributions of this study is its potential to inform policy and practice on water quality management in rural communities. Current policies and management practices in Zimbabwe have not adequately addressed the impacts of climate change on water quality, leaving rural communities to bear the brunt of this crisis (Mara, 2018). Also, the development of effective adaptation strategies for building resilience to climate change impacts on water quality. Rural communities in Bindura District are highly vulnerable to climate change impacts on water quality, and there is a need for effective adaptation strategies that can help these communities to build resilience.

Furthermore, this study will provide valuable insights into the socio-economic and environmental factors that contribute to the vulnerability of rural communities to

climate change impacts on water quality. Examining the ways in which socio-economic and environmental factors intersect to exacerbate the vulnerability of rural communities to climate change impacts on water quality, this study aims to provide a nuanced understanding of the complex factors that contribute to this vulnerability Mlambo, (2013).

The outcomes of this study can also inform the development of climate-resilient water infrastructure and management practices that prioritize the needs of rural communities. Identifying the most effective strategies for mitigating the impacts of climate change on water quality, this research can provide valuable insights for policymakers, practitioners, and community leaders working to improve water quality and promote sustainable development in rural areas (UNDP, 2019). Ultimately, this study can contribute to the achievement of the United Nations' Sustainable Development Goals, particularly Goal 6, which aims to ensure universal access to safe and affordable water.

To elaborate further, its has potential to address the knowledge gap on climate change impacts on water quality in rural Zimbabwe. Despite the growing body of research on climate change and water resources, there is a lack of studies that focus specifically on the impacts of climate change on water quality in rural areas (Mason et al., 2017). By filling this knowledge gap, this research can provide a foundation for future studies and inform the development of evidence-based policies and interventions aimed at improving water quality and reducing the vulnerability of rural communities to climate-related water stress.

Additionally, rural communities in sub-Saharan Africa are highly vulnerable to climate change impacts on water quality, and there is a need for research that examines the specific challenges and opportunities facing these communities. Focusing on Bindura District, climate change is affecting rural communities in Zimbabwe.

In addition, this study will contribute to the development of effective strategies for improving water quality management in rural communities. The study's focus on adaptation strategies for improving water quality management in Bindura District will

provide valuable insights into the ways in which rural communities can adapt to climate change impacts on water quality(Ndlovu, 2016). The study's findings will also have implications for human health, livelihoods, and well-being in Bindura District. Climate change impacts on water quality are a significant threat to human health, livelihoods, and well-being, particularly in rural communities where access to clean water is already limited.

Finally, the study's findings will provide a foundation for future research on climate change impacts on water quality in rural communities. By examining the impacts of climate change on water quality in Bindura District, this study aims to provide a nuanced understanding of the complex factors that contribute to the vulnerability of rural communities to climate change impacts on water quality. The study's findings will provide a valuable foundation for future research on this critical issue.

1.9 Delimitation

This study is geographically delimited to four specific rural areas in Bindura, Zimbabwe namely: Manhenga, Chireka, Nyava, and Musana. These areas were selected due to their unique characteristics, including a mix of communal and commercial farming, and varying levels of access to clean water and sanitation. By focusing on these specific areas, the study aims to gain a deeper understanding of the complex relationships between climate change, water quality, and community livelihoods in Bindura.

The study is also delimited to specific populations, including household heads, community leaders, and water users. Household heads were selected as they are often responsible for making decisions about water use and management within the household. Community leaders were selected due to their influence and knowledge

about community-level water management practices. Water users, including farmers, households, and institutions, were selected as they are directly impacted by changes in water quality and availability. By targeting these specific populations, the study aims to gather nuanced and context-specific insights into the impacts of climate change on water quality and community livelihoods.

The study is further delimited to the period between 2020 and 2025, with a focus on the current situation and future prospects. This time frame was selected as it allows for an examination of the current impacts of climate change on water quality and community livelihoods, as well as an exploration of potential future scenarios and adaptation strategies. By focusing on this specific time frame, the study aims to provide actionable insights and recommendations for policymakers, practitioners, and community members working to address the complex challenges posed by climate change in Bindura.

1.10 Limitations

This study has several geographical limitations. The research is limited to four specific areas in Bindura, Zimbabwe, which may not be representative of other areas in the country or region. This limitation may affect the generalizability of the findings, and caution should be exercised when applying the results to other contexts. Furthermore, the study's focus on rural areas may overlook the experiences and challenges faced by urban communities in Bindura.

The study's sampling limitations are another concern. The research relies on a sample of household heads, community leaders, and water users, which may not be representative of the entire population. The sample size may also be limited, which can affect the accuracy and reliability of the findings. Additionally, the study's reliance on self-reported data from respondents may be subject to biases and limitations, such as social desirability bias and recall bias.

The study's methodological limitations are also worth noting. The research uses a mixed-methods approach, which can be time-consuming and resource-intensive. The integration and analysis of qualitative and quantitative data may also be challenging, and the study's findings may be limited by the availability and quality of the data. Furthermore, the study's focus on a specific time frame (2020-2025) may overlook long-term trends and changes in the relationships between climate change, water quality, and community livelihoods.

Finally, the study is limited by various external factors, including cultural and social factors, climate variability, and policy and institutional limitations. The research may be affected by language barriers, social norms, and power dynamics, which can impact the accuracy and reliability of the data. Additionally, the study's findings may be limited by the availability and accuracy of water quality monitoring data, as well as the policies and institutions in place to address climate change and water quality issues in Bindura. The researcher will minimize the methodological limitations by providing a detailed methodology chapter which allows replication of the study in similar environments.

1.11 Definition of terms

Climate change refers to any significant change in the measures of climate lasting for an extended period of time. It includes changes in temperature, precipitation, and wind patterns, among others, (Intergovernmental Panel on Climate Change, 2013). Climate change means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods UN, (2015)

Water Quality: "Water quality refers to the physical, chemical, and biological characteristics of water that determine its suitability for various uses, including drinking, irrigation, and industrial purposes" (World Health Organization, 2011).

Rural areas are regions located outside cities and towns, characterized by open spaces, farmland, and lower population density compared to urban areas, often associated with a slower pace of life and a closer connection to nature (Mudombi and Muchie, 2013).

Community Livelihoods: "Community livelihoods refer to the ways in which individuals and households in a community make a living, including their access to resources, income-generating activities, and social support networks" (Chambers & Conway, 1992).

Adaptation: "Adaptation refers to the process of adjusting to actual or expected climate change and its effects, in order to moderate harm or exploit beneficial opportunities" (Intergovernmental Panel on Climate Change, 2014).

Vulnerability: "Vulnerability refers to the degree to which a system, including human populations and ecosystems, is susceptible to, and unable to cope with, adverse effects of climate change" (Intergovernmental Panel on Climate Change, 2014).

Resilience: "Resilience refers to the ability of a system, including human populations and ecosystems, to withstand, recover from, and adapt to climate-related shocks and stresses" (United Nations Development Programme, 2016).

Sustainable Development: "Sustainable development refers to development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987).

1.12 Organization of the study

CHAPTER	**CONTENTS**
1	**INTRODUCTION TO THE STUDY AND ITS CONTEXT**

	Provides the background to the study and the gap that the current study is going to cover.
2	**REVIEW OF RELATED LITERATURE** Provides the theoretical framework of the study. It also assesses the existing literature and the gaps that need further research
3	**RESEARCH METHODOLOGY** Provides the detailed report of the research methodology.
4	**DATA PRESENTATION, ANALYSIS AND DISCUSSION/INTERPRETATION** Presents analyses and interprets the research findings. It also connects the research findings to existing literature to find the patterns and change in knowledge.
5	**CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS** Summarizes the research, its findings and the conclusions drawn from the discussions. It also provides recommendations to for stakeholders and further research.

1.13 Chapter summary

This chapter introduces the research on climate change impacts on water quality, highlighting the significant effects on human health, livelihoods, and the environment in rural areas of Bindura. Climate change is altering the hydrological cycle, leading to changes in precipitation patterns, increased evaporation, and reduced groundwater recharge, ultimately affecting water quality. The research questions and objectives focus on investigating the impacts of climate change on water quality in the Bindura region and examining the effects on human health and livelihoods. This study aims to contribute to the understanding of the impacts of climate change on water quality and human livelihoods, informing policy and practice for climate change adaptation and water management. Building on this introduction, Chapter 2 will review the existing literature on climate change and water quality, exploring the theoretical frameworks and concepts that underpin this research.

CHAPTER 2

2.1 INTRODUCTION

This chapter provides a comprehensive review of the existing literature on the impact of climate change on water quality in rural communities of Bindura, with a specific focus on the research questions guiding this study. The chapter begins by outlining the theoretical framework that underpins this research, drawing on the Human Vulnerability Framework to examine the complex relationships between climate change, water quality, and rural community vulnerability. The subsequent sections delve into the subheadings of the research questions, exploring the current state of knowledge on the impact of climate change on water quality, the vulnerability of rural communities to climate-related changes in water quality, and the strategies for enhancing the adaptive capacity of rural communities. The chapter concludes by highlighting the research gaps that this study aims to address, providing a summary of the key areas that require further investigation.

2.2 THEORETICAL FRAMEWORK

Climate and water experts are confident that people living in rural areas around the world will experience major impacts from climate change through water supplies (Howard, et al., 2016). Climate-related events, such as intense rainfall, severe storms, dry spells, extremely hot days, and storm surges, damage or destroy water supply infrastructure, diminish the availability of water resources, and reduce the quality of water used for consumption. Human-induced global warming has already led to an increase in the frequency, intensity, and amount of heavy precipitation events; more frequent heatwaves; and mean sea level rise worldwide (Wright, et al., 2014). Climate-related risks for human and natural systems will continue to increase as global warming continues, especially for poor and vulnerable populations. Climate-related water safety risks, which are already important to manage, will likely become increasingly critical to address in rural areas for the foreseeable future.

According to a vulnerability theory, that seeks to enable people, particularly the most disadvantaged social groups, to address climate change impacts in general by addressing the root causes of their vulnerability (Jasen, et al., 2006). The vulnerability of people, defined as a propensity or predisposition to be adversely affected by climate change, is conceived to be strongly influenced by social and political processes (White, 2010). These socio-political processes unequally expose people to climate hazards, make them more susceptible to harm from climate change, and restrain their ability to influence responses that would benefit them (UNICEF, 2019). Climate change, in turn, exacerbates poverty and inequality, which deepen vulnerability (Khan, 2015). This approach raises questions of who is most vulnerable and why and how vulnerability is differentiated . Through the identification of who is most vulnerable to climate change impacts and why, interventions may be designed to address inequalities and empower people to more effectively respond to impacts.

In the words of, Jasen, et al, (2006) vulnerability approach to climate impacts on water safety would first seek to understand the inequalities and power relationships within a rural town, community, or household, then assess the extent to which these make people more vulnerable to reduced water safety from climate impacts. However, the WASH sector has engaged little with vulnerability approaches in relation to climate change, instead tending to evoke technological and biophysical-focused responses to climate change (White, 2010). Although it does not have explicit consideration of climate change, one example of a vulnerability approach to drinking water safety management is the Equitable Water Safety Planning guide (UNICEF, 2019).

Apart from that, Robison and Howard , (2017) alludes that the Human Vulnerability Framework (HVF) as a conceptual framework that examines the vulnerability of human populations to environmental hazards, including climate change (Blaikie et al., 1994; Wisner et al., 2004). The framework considers three key components: exposure, sensitivity, and adaptive capacity. Exposure refers to the degree to which a community is exposed to environmental hazards, such as climate-related changes in water quality. Sensitivity refers to the degree to which a community is sensitive to the impacts of environmental hazards, including their social, economic, and

environmental characteristics. The HVF can be applied to examine the vulnerability of rural communities to climate-related changes in water quality. Rural communities may be exposed to changes in water quality due to climate-related changes in precipitation and temperature patterns. They may also be sensitive to changes in water quality due to their reliance on local water sources for drinking, agriculture, and other livelihood activities. Applying the HVF, helps identify strategies to enhance the adaptive capacity of rural communities and reduce their vulnerability to climate-related changes in water quality (IPCC, 2014).

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Apart from that, the Sustainable Livelihoods Framework (SLF) is a conceptual framework that examines the livelihoods of individuals, households, and communities, and how they are affected by external factors such as climate change (Brooks, et al. 2016). The framework considers five key assets or capitals: natural capital, social capital, human capital, physical capital, and financial capital. These assets are used to make a living and are interconnected, influencing one another. In the context of your study, the SLF can be applied to examine the impact of climate change on the livelihoods of rural communities, with a specific focus on water quality. Climate-related changes in water quality can affect the natural capital (water resources), social capital (social relationships and networks), human capital (health and well-being), physical capital (irrigation systems and water infrastructure), and financial capital (water-based livelihoods) of rural communities (Hansen, 2011). The SLF, is a strategy for enhancing the sustainability of rural livelihoods and mitigating the impacts of climate change on water quality.

Smit and wandel, (2006) highlighted the Adaptive Capacity Theory suggests that the ability of rural communities to adapt to climate-related changes in water quality is influenced by various factors, including economic resources, social networks, knowledge, and technology. In the context of your research question, which explores the impact of climate change on water quality in rural communities, the Adaptive Capacity Theory can help explain why some communities are better able to adapt to these changes than others. By examining the factors that influence adaptive capacity, your study can identify strategies for enhancing the ability of rural communities to adapt to climate-related changes in water quality.

In addition, the Adaptive Capacity Theory can also inform strategies for building resilience in rural communities (IPCC, 2004). For example, this might explore how rural communities can access and utilize climate information and early warning systems to prepare for climate-related changes in water quality. Additionally, the theory can inform strategies for developing and implementing effective water management practices, building and maintaining social networks and partnerships, and developing and utilizing innovative technologies and practices to enhance water management and adaptation to climate change. This theory, can provide insights into the complex relationships between climate change, water quality, and rural community adaptation, and inform strategies for enhancing the resilience and sustainability of rural communities.The suggests that individuals' perceptions of risk, influence their behavior and decision-making related to that risk (Slovic, 1987; Kasperson et al., 1988). In the context of climate change and water quality, risk perception refers to how individuals perceive the likelihood and potential impact of climate-related changes in water quality.

According to Slovic (1987), risk perception is influenced by factors such as personal experience, trust in institutions, and social and cultural norms. For example, individuals who have experienced climate-related events, such as droughts or floods, may perceive the risk of climate-related changes in water quality as higher than those who have not had such experiences. Kasperson et al. (1988) note that risk perception is also influenced by the "social amplification of risk," which refers to how social and cultural factors can amplify or attenuate risk perceptions. In the context of climate change and water quality, social amplification can occur through various channels, such as media coverage, public discourse, and social networks. By understanding how individuals perceive the risks associated with climate-related changes in water quality, strategies can be identified to promote adaptive behaviors and mitigate the impacts of climate change on water quality (Slovic, 1987; Kasperson et al., 1988).

OVERVIEW OF IMPACT OF CLIMATE CHANGE ON WATER SOURCES

Climate change has been identified as one of the most significant threats to global water resources, with far-reaching implications for human health, livelihoods, and ecosystems (IPCC, 2013). Research has shown that climate change is altering the global water cycle, leading to changes in precipitation patterns, increased frequency of extreme weather events, and rising water temperatures (Bates et al., 2008). These changes have significant implications for water quality, particularly in rural communities where access to clean water is already limited.

Also, Studies have shown that climate change is exacerbating water pollution in rural communities, particularly in sub-Saharan Africa (UNEP, 2010). Changes in precipitation patterns and increased frequency of floods are contaminating water sources with pollutants and sediments, further compromising water quality (Mwakalila et al., 2011). Additionally, the increased frequency of droughts is forcing rural communities to rely on unsafe water sources, exacerbating the risk of waterborne diseases (WHO, 2014). Research has also shown that rural communities in sub-Saharan Africa are highly vulnerable to climate change impacts on water quality due to limited access to clean water, sanitation, and hygiene facilities (Hunter et al., 2010).

Despite the critical nature of this issue, there is a dearth of research on the impacts of climate change on water quality in rural communities, particularly in sub-Saharan Africa (McCartney et al., 2012). Existing studies have focused primarily on urban areas, neglecting the unique challenges and vulnerabilities of rural communities (Howard et al., 2016). Furthermore, current policies and management practices in many African countries have not adequately addressed the impacts of climate change on water quality, leaving rural communities to bear the brunt of this crisis (Mugabe et al., 2015).

Research has also highlighted the need for effective adaptation strategies to improve water quality management in rural communities (UNFCCC, 2011). Adaptation strategies such as rainwater harvesting, water conservation, and watershed

management have been shown to be effective in improving water quality and reducing the vulnerability of rural communities to climate change impacts (Mwakalila et al., 2011). However, the adoption of these strategies is often limited by lack of awareness, inadequate resources, and institutional barriers (Nyagwande et al., 2013).

According to Bates, etal, (2008), in Bindura recently, people have witnessed an upsurge of worldwide interest in potential impacts of climate change on water resources. Climate change is often entwined with alteration of water quantity as well as quality, aggravating the fast-growing water crisis. Over the past few decades, the negative effects of climate extremities are reflected in hydrological cycle, viz., pronounced shifts in global precipitation patterns and increased atmospheric water vapor content, glacier melting, floods, soil erosion, and drought etc. This situation substantially hinders the progress toward the attainment of Sustainable Development Goals (SDGs), thus jeopardizing the needs of future generations. It is therefore necessary to scientifically address the water security issues triggered by the escalating atmospheric and ocean temperatures.

In addition, Cannon and Muller (2010), adds that water resource management has an obvious impact on a wide range of policy sectors, including energy, health, food security, and environment. As a result, practitioners need to design appropriate adaptation and mitigation strategies across diverse water-dependent sectors. However, there is a call for scrutinizing the current knowledge gaps in climate change vis-a-vis its implications on water resources. Owing to the complexities of climate system, anticipating these impacts is extremely challenging. Hence climate models related to the hydrological cycle provides a framework to conceptualize future scenario which is important for effective decision making.

Furthermore, water scarcity is described as a condition where water demand exceeds over available water supply. A country or a region faces “water scarcity” when the availability of natural hygienic water falls below 1000 m^3 per person per year (Pereira et al., 2002; Dehghani et al., 2019). Water scarcity is something that is not a concern with only a single living being at a particular location and time, but it affects a larger population within a certain geographic region (e.g., country) and pertains to larger timescales (years or months). It can occur because of natural low water availability as

well as human-imposed activities to degrade the available natural water. The natural water body has the potential to renew or restore its originality. However, water pollution is the dominant factor to aggravate water scarcity by degrading the quality of water resources. The detrimental effect caused by nature and human intervention has led to severe water challenges and water scarcity, which is elaborated in the upcoming section.

In conclusion, the literature highlights the critical nature of climate change impacts on water quality in rural communities, particularly in sub-Saharan Africa. Despite the significance of this issue, there is a need for further research to better understand the impacts of climate change on water quality and to identify effective adaptation strategies for improving water quality management in rural communities. This study aims to contribute to this knowledge gap by investigating the impacts of climate change on water quality in Bindura District, Zimbabwe.

2.4 AN OVERVIEW OF CLIMATE CHANGE

According to IPCC's Sixth Assessment Report, human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming. The 10-year average global surface temperature for 2011-2020 is estimated to be 1.1 °C above the 1850-1900 pre-industrial baseline (IPCC AR6 Synthesis Report)

Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals (Mugabe, 2015). Only with deep, rapid and sustained reductions in greenhouse gas emissions can we limit the temperature increases and avoid the worst impacts of climate change. At its core, climate change refers to the long-term warming of the planet, which is primarily caused by the increasing levels of greenhouse gases in the Earth's atmosphere. These gases, such as carbon dioxide and methane, trap heat from the sun and prevent it from being released back into space, leading to a rise in global temperatures. The consequences of climate change are widespread and varied, and include rising sea

levels, more extreme weather events, and changes in precipitation patterns (Hunter, 2020).

In addition, one of the primary causes of climate change is the burning of fossil fuels, such as coal, oil, and gas, for energy. This releases large amounts of carbon dioxide into the atmosphere, which contributes to the greenhouse effect. Deforestation and land use changes, such as the conversion of natural habitats to agricultural land or urban areas, are also significant contributors to climate change. These activities release stored carbon into the atmosphere and reduce the ability of forests to act as carbon sinks. Additionally, the production of meat, especially beef, and other animal products leads to the release of methane and nitrous oxide, two potent greenhouse gases (Nyagwande, 2013).

Recently, the effects of climate change are already being felt around the world. Rising global temperatures are causing more frequent and severe heatwaves, droughts, and storms (Wright et al., 2020). Sea levels are rising, leading to coastal erosion and flooding. Changes in precipitation patterns are altering the distribution of water resources, leading to more frequent and severe floods and droughts. These impacts have significant implications for human societies, including food insecurity, water scarcity, and human migration and conflict (Howard, 2019). Climate change also has significant economic impacts, from damage to infrastructure and increased healthcare costs, to impacts on tourism and recreation.

According to Calow, (2010) the significant challenges posed by climate change, there are many solutions that can help to reduce greenhouse gas emissions and mitigate its impacts. Transitioning to renewable energy sources, such as solar and wind power, can significantly reduce emissions from the energy sector. Improving energy efficiency in buildings, transportation, and industry can also reduce emissions. Electrifying transportation and implementing carbon capture and storage technologies can also reduce emissions from industrial sources. Sustainable land use practices, such as reforestation and agroforestry, can sequester carbon dioxide and reduce emissions.

Furthermore, climate change requires immediate attention and action. Its causes are complex and multifaceted, but its impacts are clear and far-reaching. By transitioning to renewable energy sources, improving energy efficiency, and implementing sustainable land use practices, we can reduce greenhouse gas emissions and mitigate the impacts of climate change. It will require a coordinated effort from governments, businesses, and individuals around the world, but it is a challenge that we must meet in order to ensure a sustainable future for all. The importance of addressing climate change cannot be overstated. As noted by the Intergovernmental Panel on Climate Change (IPCC), the scientific evidence for human-caused climate change is overwhelming (IPCC, 2013). The IPCC also notes that "without additional mitigation efforts, global emissions will continue to rise, leading to a global average temperature increase of 3.2°C to 5.4°C above pre-industrial levels by the end of the century" (IPCC, 2013). This highlights the urgent need for action to reduce greenhouse gas emissions and mitigate the impacts of climate change.

In addition to the environmental impacts of climate change, there are also significant economic implications. A study by the Economist Intelligence Unit found that climate change could lead to losses of up to 11% of global GDP by 2100 (Bates, 2019). This highlights the need for businesses and governments to take action to mitigate the impacts of climate change and reduce greenhouse gas emissions. Futherore, fossil fuels – coal, oil and gas – are by far the largest contributor to global climate change, accounting for over 75 per cent of global greenhouse gas emissions and nearly 90 per cent of all carbon dioxide emissions (IPCC, 2019). As greenhouse gas emissions blanket the Earth, they trap the sun’s heat. This leads to global warming and climate change. The world is now warming faster than at any point in recorded history. Warmer temperatures over time are changing weather patterns and disrupting the usual balance of nature. This poses many risks to human beings and all other forms of life on Earth.

Acoording to Brooks et al., (2013) climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent human-induced changes in the composition of the atmosphere, ocean or in land use. “Anthropogenic” or “human-induced climate change” results

from human activities which are already affecting many weather and climate extremes in every region across the globe. These can include: burning of fossil fuels, deforestation,land use and land use changes, livestock management, fertilisation, waste management, and industrial processes. Human-induced climate change has led to widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere, affecting many weather and climate extremes in every region across the globe and causing widespread adverse impacts and related losses and damages to nature and people.

Finally, it is worth noting that climate change is not just an environmental issue, but also a social justice issue. The impacts of climate change disproportionately affect vulnerable populations, such as low-income communities, indigenous peoples, and small-island developing states (UNFCCC, 2015). Therefore, it is essential that efforts to address climate change prioritize the needs and perspectives of these communities.

2.5. THE IMPACTS OF CLIMATE CHANGE ON WATER QUALITY

Climate change is having a profound impact on water quality around the world. Rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events are all contributing to declining water quality (IPCC, 2013). One of the primary ways that climate change is impacting water quality is through the increased frequency and severity of floods. Floods can contaminate water sources with pollutants and sediments, making them unsafe for human consumption (US EPA, 2019). For example, a study by the National Oceanic and Atmospheric Administration (NOAA) found that flooding in the Midwest region of the United States led to significant increases in bacterial contamination of water sources (NOAA, 2020).

In addition to floods, climate change is also leading to more frequent and severe droughts. Droughts can have a devastating impact on water quality, as they can lead to the concentration of pollutants in water sources (WHO, 2018). This can make water sources unsafe for human consumption and can also harm aquatic ecosystems.

Furthermore, droughts can also lead to the increased use of groundwater, which can lead to land subsidence and other environmental problems (UN Water, 2019). For example, recently there is increased borehole drilling from 2012 to 2016 led to significant declines in groundwater levels, resulting in land subsidence and increased risk of water contamination ( ).

Climate change is also altering the patterns of precipitation around the world. This can lead to changes in the flow of rivers and streams, which can impact water quality (IPCC, 2013). For example, changes in precipitation patterns can lead to the increased transport of pollutants and sediments into water sources. This can make water sources unsafe for human consumption and can also harm aquatic ecosystems. Furthermore, changes in precipitation patterns can also lead to the increased frequency and severity of floods and droughts, which can have devastating impacts on water quality (US EPA, 2019).

Rising temperatures are also having a significant impact on water quality. Warmer water temperatures can lead to the increased growth of algae and other aquatic plants (WHO, 2018). This can lead to the depletion of oxygen in water sources, making them unsafe for human consumption and harming aquatic ecosystems. Furthermore, warmer water temperatures can also lead to the increased survival and spread of waterborne pathogens (UN Water, 2019). For example, a study by the Centers for Disease Control and Prevention (CDC) found that warmer water temperatures in the United States led to significant increases in the incidence of waterborne diseases (CDC, 2019).Climate change is also leading to the increased frequency and severity of heatwaves. Heatwaves can have a devastating impact on water quality, as they can lead to the increased evaporation of water sources (IPCC, 2013). This can lead to the concentration of pollutants in water sources, making them unsafe for human consumption. Furthermore, heatwaves can also lead to the increased use of water for cooling, which can lead to water scarcity (US EPA, 2019).

In addition to these impacts, climate change is also altering the chemistry of water sources. For example, the increased absorption of carbon dioxide by oceans is leading to ocean acidification (WHO, 2018). This can have a devastating impact on aquatic ecosystems, particularly those that rely on calcium carbonate, such as coral reefs.

Furthermore, ocean acidification can also lead to the increased release of pollutants from sediments and rocks, which can further degrade water quality (UN Water, 2019).

Climate change is also leading to the increased frequency and severity of wildfires. Wildfires can have a significant impact on water quality, as they can lead to the increased transport of pollutants and sediments into water sources (IPCC, 2013). This can make water sources unsafe for human consumption and can also harm aquatic ecosystems. Furthermore, wildfires can also lead to the increased use of water for firefighting, which can lead to water scarcity (US EPA, 2019).

The impacts of climate change on water quality are not limited to surface water sources. Climate change is also impacting groundwater quality, particularly in areas where the water table is shallow (WHO, 2018). For example, the increased frequency and severity of floods can lead to the contamination of groundwater sources with pollutants and sediments. This can make groundwater sources unsafe for human consumption and can also harm aquatic ecosystems. In many parts of the world, climate change is also leading to the increased salinization of water sources. This can occur when seawater infiltrates into freshwater sources, making them undrinkable (UN Water, 2019). The increased salinization of water sources can have significant impacts on human health, particularly in areas where access to clean drinking water is already limited. Furthermore, the increased salinization of water sources can also lead to the increased use of desalination plants, which can have significant environmental impacts.

2.6. BINDURA RURAL COMUNITIES AND WARER QUALITY

Rural communities in Bindura, Zimbabwe, face significant challenges in accessing clean and safe water. The district is characterized by a semi-arid climate, with limited rainfall and a high evaporation rate, making water scarcity a major concern (Makurira et al., 2016). The rural communities in Bindura rely heavily on groundwater and

surface water sources, which are often contaminated with pollutants and pathogens, posing serious health risks to the communities. A study conducted by the Zimbabwe National Water Authority (ZINWA) found that the water quality in Bindura is compromised by high levels of total dissolved solids, nitrates, and bacteria (ZINWA, 2018). The study attributed the poor water quality to the lack of proper waste management, agricultural runoff, and inadequate treatment of wastewater. These findings are consistent with other studies conducted in rural Zimbabwe, which have highlighted the need for improved water quality management in rural areas (Moyo et al., 2017).

The rural communities in Bindura have limited access to piped water, and many rely on boreholes and wells for their water supply. However, these sources are often contaminated with pollutants and pathogens, posing serious health risks to the communities (Makurira et al., 2016). A study conducted by the University of Zimbabwe found that the water quality in rural Bindura is compromised by high levels of Escherichia coli (E. coli), which is a common indicator of fecal contamination (University of Zimbabwe, 2019). Climate change is exacerbating the water quality challenges faced by rural communities in Bindura. Changes in precipitation patterns and increased frequency of extreme weather events are leading to increased runoff and erosion, which can contaminate water sources (Mugabe et al., 2015). Furthermore, climate change is altering the distribution of water resources, leading to increased competition for limited water resources (Mwakalila et al., 2011).

The rural communities in Bindura have limited capacity to manage their water resources effectively. The lack of adequate infrastructure, limited financial resources, and inadequate institutional capacity hinder the ability of rural communities to manage their water resources sustainably (Moyo et al., 2017). Furthermore, the lack of awareness and education on water quality management among rural communities exacerbates the water quality challenges faced by these communities. However, the Zimbabwean government has implemented several initiatives aimed at improving water quality management in rural areas. The National Water Policy (2013) emphasizes the need for integrated water resources management, which includes water quality management (Government of Zimbabwe, 2013). Furthermore, the Zimbabwe National Water Authority (ZINWA) has implemented several water

quality monitoring programs aimed at improving water quality management in rural areas (ZINWA, 2018).

Despite these efforts, significant challenges remain in ensuring access to clean and safe water for rural communities in Bindura. The lack of adequate infrastructure, limited financial resources, and inadequate institutional capacity hinder the ability of rural communities to manage their water resources sustainably (Moyo et al., 2017). Furthermore, the lack of awareness and education on water quality management among rural communities exacerbates the water quality challenges faced by these communities. To address the water quality challenges faced by rural communities in Bindura, there is a need for a multi-faceted approach that involves government, civil society, and local communities. This approach should include the development of adequate infrastructure, capacity building for local communities, and awareness and education programs on water quality management (Makurira et al., 2016).

In conclusion, rural communities in Bindura, Zimbabwe, face significant challenges in accessing clean and safe water. The lack of adequate infrastructure, limited financial resources, and inadequate institutional capacity hinder the ability of rural communities to manage their water resources sustainably. To address these challenges, there is a need for a multi-faceted approach that involves government, civil society, and local communities.

2.7 MITIGATION AND ADAPTATION

Adopting sustainable agricultural practices is essential for climate mitigation and water conservation. Strategies such as agroforestry, conservation agriculture, and precision farming help reduce GHG emissions from agricultural activities (Smith et al., 2014). Improved livestock management, efficient irrigation techniques, and reductions in food waste also contribute to emission reductions. Implementing carbon pricing mechanisms, such as carbon taxes and cap-and-trade systems, provides

economic incentives for emission reductions. These mechanisms place a price on carbon emissions, encouraging industries and individuals to adopt cleaner technologies and practices (Stiglitz et al., 2017). Market mechanisms like emissions trading enable the trading of emission allowances, promoting cost-effective emission reductions.

Community-based initiatives are essential for promoting water conservation and improving water security in rural areas of Chireka. Community water management involves establishing community water management committees to manage water resources, resolve conflicts, and promote water conservation. These committees play a crucial role in ensuring that water resources are managed effectively and that the needs of all community members are met. Water education and awareness are also critical components of community-based initiatives (sango et al., 2025). Educating communities about water conservation practices and promoting water-saving behaviors can help reduce water consumption and improve water security. Community-based water conservation projects, such as rainwater harvesting systems or water-efficient irrigation systems, can provide a reliable source of clean water and promote water conservation.

According to Nyagwande (2013) water-efficient technologies are designed to reduce water consumption while maintaining or improving the quality of life. Drip irrigation, for example, delivers water directly to the roots of plants, reducing evaporation and runoff. This method is particularly effective in areas with limited water resources, as it helps to conserve water and reduce the energy required for irrigation. Low-flow toilets and showerheads are also effective in reducing water consumption in households. These fixtures use significantly less water than traditional models, making them an essential component of water-efficient households. Water-efficient

appliances, such as washing machines and dishwashers, also play a crucial role in reducing water consumption. By adopting these technologies, rural communities can significantly reduce their water footprint and improve their overall water security.

Policy and institutional support are essential for promoting water conservation and improving water security in rural areas (Howard ,2019). Water policy and regulations play a crucial role in ensuring that water resources are managed effectively and that water conservation practices are promoted. Water pricing and incentives can also encourage water conservation and efficient use of water resources. Capacity building and training programs for water managers, farmers, and communities can help build their capacity to manage water resources effectively and promote water conservation. By providing policy and institutional support, governments and organizations can help ensure that water conservation efforts are successful and sustainable.

Developing drought-resistant crops is an effective way to adapt to the impacts of climate change on water quality. Drought-resistant crops can help to reduce the impacts of droughts on agriculture and minimize the amount of water used for irrigation (IPCC, 2013). According to the Food and Agriculture Organization (FAO) of the United Nations, developing drought-resistant crops can help to improve crop yields and reduce water consumption (FAO, 2019).

2.8 SUMMARY

This study explores the issue of Climate change and declining water levels in rural areas, with a focus in Bindura. The theoretical framework highlights the importance of understanding the complex relationships between climate change, human activities, natural factors, and water quality. The research overview outlines the objectives and methodology of the study, which aims to investigate the causes and effects of water pollution in rural areas. The analysis of rural water quality reveals that agricultural activities, rural infrastructure, natural factors, and human activities are major

contributors to water pollution, with significant health impacts on rural communities. The study concludes that solutions and mitigation strategies, such as improved agricultural practices, enhanced infrastructure, and water conservation practices, are necessary to address these issues and protect the health and well-being of rural communities.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INRODUCTION

This chapter outlines the research methodology employed in this study, which investigates the impact of climate change on rural water quality in four districts of Bindura. The study aims to explore the effects of climate change on water quality and the mitigation measures on rural water quality and to identify strategies for improving water quality in the face of climate change. To achieve this, a research design was developed, which provides a framework for collecting and analyzing data. This chapter provides an overview of the research philosophy, methodology, research design, population and sample, sampling methods, data collection methods, validity and reliability, data presentation and analysis, and ethical considerations that guided this study.

3.2 RESEARCH PARADIGM

A research paradigm is a framework or approach that guides the conduct of research, shaping the way researchers design, collect, and analyze data (Creswell, 2007). It encompasses the researcher's philosophical assumptions, values, and beliefs about the nature of reality, knowledge, and how we can understand the world. Pragmatism is a research paradigm that focuses on what works in practice, rather than adhering to a specific ideology or methodology (Cresswell and Miller, 2000). Pragmatic researchers aim to find solutions to real-world problems, and are often concerned with understanding the practical implications of their research (Stern, 2007).This study is grounded in the pragmatic research paradigm, which emphasizes practicality and effectiveness in addressing real-world problems.

Through pragmatic research, the researcher aim to find solutions to the challenges faced by rural communities in terms of water quality and climate change. This paradigm allows the researcher to focus on what works in practice, rather than adhering to a specific ideology or methodology. By adopting a pragmatic approach, the research can combine multiple methods and approaches to achieve a more comprehensive understanding of the research problem.

Furthermore the pragmatic paradigm is particularly well-suited to this study because it recognizes the complexity and nuance of the research problem (Cohen, etal). Climate change and water quality are multifaceted issues that require a comprehensive and practical approach. Emphasizing practicality and effectiveness, pragmatism enables me to identify solutions that can be implemented in rural settings of Bindura. Furthermore, the pragmatic paradigm allows for flexibility in the research design and methodology, which is critical in addressing the dynamic and changing nature of climate change and water quality (Creswell, 2007).

Also pragmatic research enables the researcher to be concerned with understanding the practical implications of the research and identifying solutions that can be implemented by stakeholders, including the village council and the urban council. This paradigm enables me to engage with rural communities and other stakeholders to understand their needs and concerns, and to develop solutions that are tailored to their specific context. Adopting a pragmatic approach allows the researcher to ensure that the research is relevant, practical, and effective in addressing the challenges faced by rural communities in terms of water quality and climate change in Bindura.

3.3 RESEARCH DESIGN

Research design refers to the overall structure and plan of a study, outlining the systematic steps and procedures for data collection and analysis (Creswell, 2013). It provides a blueprint for addressing research questions or objectives and guides researchers in making informed decisions throughout the research process. In the case

of this study on the impact of climate change on rural water quality in Bindura District, mixed approach research design was chosen.

The research design adopted for this study is a mixed-methods approach, combining both qualitative and quantitative data collection and analysis methods. This approach allows for a comprehensive understanding of the research problem, enabling the researcher to capture both numerical data and narrative insights from participants (Merriam, 1998). The research design provides a clear plan for collecting and analyzing data, ensuring that the study's objectives are met and that the research questions are adequately addressed.

A mixed-methods research design, combines both quantitative and qualitative approaches to investigate the impact of climate change on rural water quality (Martens, 2015). The quantitative component involves water quality sampling, which will provide objective data on the physical, chemical, and biological characteristics of rural water sources. Water samples will be collected from various locations and analyzed using standard laboratory procedures to determine parameters such as pH, turbidity, and nutrient levels. This quantitative data will provide a comprehensive understanding of the current state of rural water quality and help identify any trends or patterns (Martens, 2015).

The qualitative component involves in-depth interviews and observations within rural households and community members, which will provide subjective insights into their experiences, perceptions, and concerns related to water quality and climate change (Stern, 2007). The interviews will be semi-structured, allowing for open-ended discussions and exploration of themes and issues that may not have been anticipated. The qualitative data will be analyzed using thematic analysis, which will help identify patterns and themes in the data. Combining both quantitative and qualitative approaches, this mixed-methods design will provide a more comprehensive understanding of the impact of climate change on rural water quality, and will help identify practical solutions to address the challenges faced by rural communities (UNEP, 2007).

3.5 RESEARCH POPULATION

The research population for this study comprises rural communities residing in four villages: Manhenga, Nyava, Chireka, and Masana. These communities are directly affected by changes in water quality levels, which impact their livelihoods, health, and overall well-being. A total of 40 participants will be selected for this study, with 10 representatives from each of the four villages. The participants will provide valuable insights into the effects of climate change on water quality, as well as their experiences, perceptions, and coping strategies. By focusing on these rural communities, the study aims to gain a deeper understanding of the complex relationships between climate change, water quality, and community resilience.

The selection of these villages is based on their proximity to water bodies and their vulnerability to climate-related impacts. The participants will include farmers, community leaders, and other stakeholders who have firsthand experience with the challenges posed by changes in water quality. Through their participation, the study will gather rich, contextual data that can inform policy and practice aimed at improving water quality and enhancing community resilience in the face of climate change

Water management officials and other stakeholders who are responsible for overseeing and managing water resources in Bindura are also included in this population. These individuals may work in government agencies, water treatment plants, or other organizations that play a critical role in ensuring the quality and safety of water supplies in the region. Studying this population helps gain a deeper understanding of the complex relationships between climate change, water quality, and the social and economic systems that depend on these resources. This knowledge can inform the development of effective strategies and policies to mitigate the impacts of climate change on water quality in Bindura and to promote sustainable and equitable management of water resources in the region.

3.6 RESEARCH SAMPLE AND SAMPLING PROCEDURE

The research sample consists of 40 participants selected from four rural villages: Manhenga, Nyava, Chireka, and Masana. The participants include farmers, community elders, and village leaders who have intimate knowledge of the local environment and are directly affected by changes in water quality. This sample size is considered suitable for an in-depth, qualitative study that aims to gather rich, contextual data on the impacts of climate change on water quality in rural communities.

3.6.1Sampling Technique

The sampling technique employed in this study is purposive sampling, a non-probability sampling method that involves selecting participants based on their relevance to the research question (Garg, 2016). This technique is particularly useful in rural settings where specific individuals, such as farmers and community leaders, possess valuable knowledge and experiences related to water quality and climate change. Purposive sampling allows the researcher to target participants who are most likely to provide insightful and meaningful data, thereby enhancing the validity and reliability of the study's findings.

Purposive sampling is well-suited for this study because it enables the researcher to select participants who are knowledgeable about the local environment and have firsthand experience with the impacts of climate change on water quality (Andrade, 2020). In rural communities, where traditional knowledge and practices are often prevalent, purposive sampling allows the researcher to tap into the expertise of community elders and farmers who have lived experience with climate-related changes. By targeting specific participants, the study can gather nuanced and context-specific data that reflects the complexities of climate change and water quality in rural settings. This approach ensures that the research findings are grounded in the realities

of the community, thereby increasing their relevance and applicability to policy and practice.

Villages and households

Village	Number of households
Manhenga	10
Chireka	10
Nyava	10
Musana	10

3.7 RESEARCH INSTRUMENTS

A research instrument is a tool used to collect data in a research study. According to Given (2008). In this case surveys/questionnaires structured or semi-structured tools to collect self-report data (Fowler, 2009). In-depth, semi-structured, or structured conversations to gather data (Kvale, 2007) and observations: Systematic observations of behaviors, practices, or phenomena (Angrosino, 2007).

3.7.1 The questionnaire

A questionnaire is a research instrument used to collect data through a series of questions, typically in written or digital form (Martens, 2015). Its designed to gather information, opinions, or behaviors from respondents. Open-ended questionnaires are research instruments that allow respondents to provide detailed, qualitative answers to

questions in a free-response format, without pre-defined options. This format captures rich, nuanced responses, offering in-depth insights into experiences, attitudes, or opinions. However, analyzing open-ended responses can be time-consuming and subjective, they are ideal for exploratory research, discovering new themes, and gathering contextual information, making them a valuable tool for qualitative research and pilot studies.

According to Cohen, et al. (2000) a questionnaire is a self-report instrument used to collect data through a series of questions that participants answer on their own. In this study, the questionnaire will be used to gather quantitative data on demographic characteristics, water usage patterns, and perceptions of climate change impacts on water quality. The questionnaire is an important instrument in data collection because it allows for the collection of data from a large number of participants, providing a broad understanding of the research topic. It is also a cost-effective and efficient way to gather data, especially in rural areas where participants may be dispersed.

Questionnaires are a widely used research instrument due to their cost-effectiveness and ability to reach a large sample size (Creswell, 2014). They allow researchers to collect data from a diverse population, providing insights into attitudes, behaviors, and opinions. Standardized questionnaires ensure consistency in questioning, reducing bias and increasing reliability (Fowler, 2014). However, questionnaires also have limitations. Response bias and low response rates can impact the validity and generalizability of findings (Dillman et al., 2014). Additionally, self-reporting limitations and lack of control over respondents' understanding can affect data quality. Despite these limitations, questionnaires remain a valuable tool in research, offering a flexible and efficient means of data collection when designed and administered effectively.

3.7.2 The in-depth interviews

In-depth interviews are a qualitative data collection instrument that involves conducting detailed, semi-structured, or structured conversations with participants (Lawton, 2012). In this study, in-depth interviews will be conducted with key stakeholders, including farmers, community leaders, and local experts, to gather data on their experiences, perceptions, and coping strategies related to climate change and water quality. In-depth interviews are an important instrument in data collection because they provide rich, nuanced data that can help to contextualize and deepen the understanding of the research topic. They also allow participants to share their stories and experiences in their own words, providing a more detailed and personal understanding of the research issue.

Following the questionnaire administration, in-depth interviews will be conducted with key stakeholders, including farmers, community leaders, and local experts. The interviews will be scheduled in advance, and participants will be informed about the purpose and procedures of the study. The interviews will be audio-recorded, with participants' consent, to ensure accurate data collection. This will allow for a more in-depth exploration of the research topic and provide rich, nuanced data. Conducting in-depth interviews involves engaging with participants in a conversational manner to gather detailed and nuanced information about their experiences and perspectives (Garg, 2016). The interviews should be conducted in a comfortable and private setting, free from distractions and interruptions. The researcher should establish a rapport with the participant, creating a safe and non-judgmental space for them to share their thoughts and feelings.

The use of interview equipment, such as audio recorders or note-taking materials, is essential for capturing the data from the in-depth interviews (Peterson,2001). The equipment will be selected based on the research question and the preferences of the participant.

Finally, all data collected will be stored securely and confidentially. Data will be anonymized and coded to protect participant identities. The data will be stored in accordance with relevant data protection regulations and guidelines. This will ensure that the data is protected and that participants' confidentiality is maintained. Following this procedure, the study aims to collect high-quality, reliable, and valid

data that can inform the research question and contribute to the advancement of knowledge in the field.

3.7.3 Observations

Observation in research is a fundamental data collection method that involves systematically watching and recording behaviors, situations, or subjects. It offers firsthand knowledge and original insights, providing a direct way to gather information (Peterson,2015). Researchers use observation to understand phenomena, document events, and analyze patterns. This method allows for capturing details that might be missed by other techniques, such as questionnaires or interviews.

Observations involve the systematic observation and recording of behaviors, events, or phenomena in a natural or controlled setting. In this study, observations will be used to gather data on water quality parameters, agricultural practices, and community behaviors. Observations are an important instrument in data collection because they provide a more objective and direct measure of behaviors and phenomena, reducing the reliance on self-report data. They also allow researchers to gather data that may not be accessible through other methods, such as questionnaires or interviews, providing a more comprehensive understanding of the research topic.

3.8 DATA COLLECTION PROCEDURE

A data collection procedure is a systematic approach used to gather and record data for research purposes (Singer, 2003). It involves identifying data sources, selecting appropriate data collection tools, and preparing for data collection. This may include obtaining necessary permissions, training data collectors, and establishing protocols to ensure data accuracy and consistency. By following a well-planned procedure, the

researcher can ensure that their data is reliable, valid, and relevant to the research question.

The data collection procedure for this study will begin with the administration of a questionnaire to the selected participants. The questionnaire will be developed and pilot-tested with a small group of participants to ensure its validity and reliability. Participants will be provided with clear instructions on how to complete the questionnaire, and they will be given the option to complete it in-person or through a survey platform.

Observations will also be conducted as part of the data collection procedure. Observation sites will be selected based on the research question and study design. The observations will be conducted in a systematic and structured manner, using a pre-designed observation protocol. Field notes and photographs may be taken to supplement the observation data. This will provide a more objective and direct measure of behaviors and phenomena, reducing the reliance on self-report data.

3.9 DATA ANALYSIS PROCEDURE

Data analysis is a crucial step in the research process that involves interpreting and transforming raw data into meaningful insights and conclusions (Tyler, 2000) To analyze data effectively, it is essential to start by preparing the data, which involves cleaning and organizing it to ensure accuracy and completeness. This step is critical in ensuring that the data is reliable and can be used to draw valid conclusions.

Once the data is prepared, the next step is to choose the right analysis method. This involves quantitative or qualitative analysis methods, depending on the nature of the data and the research question to be used. Quantitative analysis involves using statistical methods to analyze numerical data, while qualitative analysis involves using thematic or content analysis to analyze non-numerical data. The choice of

analytical method, helps the researcher to ensure that their findings are valid and reliable.

After choosing the analysis method, the next step is to apply analysis techniques to the data. This may involve calculating descriptive statistics, such as means and frequencies, or using inferential statistics to identify relationships and patterns in the data. For qualitative data, thematic analysis may be used to identify and code themes and patterns. Applying these techniques, helps the researcher to uncover insights and patterns in the data that can inform their research question.

The final step in data analysis is to interpret and present the findings. This involves identifying patterns and trends in the data, drawing conclusions, and validating the results. Researchers will also present their findings in a clear and concise manner, using tables, figures, and graphs to visualize the data. By doing so, researchers can effectively communicate their findings and contribute to the advancement of knowledge in their field.

3.10 Validity and reliability

These methods help to ensure that the data collected is consistent and accurate, and that the findings are representative of the population being studied. To further increase reliability, consider using multiple data collection methods, conducting repeat measurements, and using calibrated and validated equipment for water analysis.

The use of observations on water quality in relation to climate change in the 4 villages has proved reliable. The quality of the data collected is crucial, and it's essential to ensure that standardized methods and instruments were used to minimize errors and biases. To improve the reliability of the observations, it's essential to use standardized methods, increase sampling frequency, and ensure that observers are trained and instruments are calibrated. Data validation through quality control checks and

comparisons with other data sources can also help to increase confidence in the findings. Considering these factors and limitations, we can better evaluate the reliability of the observations and make more informed conclusions about the relationship between water quality and climate change in the 4 villages.

3.11ETHICAL CONSIDERARIONS

The relevant authorities at Bindura University of Science Education (BUSE) have approved this research project, and the necessary permissions have been obtained to conduct the study. A research letter was developed and submitted to the university's ethics committee, outlining the research purpose, methodology, and potential risks and benefits. Upon approval, permission was granted to proceed with the research, ensuring that the study is conducted in accordance with the university's research ethics and standards. Additionally, informed consent will be obtained from all participants, and their rights and dignity will be respected throughout the research process.

In conducting research on the impact of climate change on water quality, the researcher must prioritize ethical considerations to ensure the well-being and dignity of participants. One crucial aspect is obtaining informed consent from household members who will be participating in the study. This involves clearly explaining the purpose of the research, potential risks and benefits, and ensuring that participants understand their rights and responsibilities. By doing so, the researcher can build trust with participants and ensure that they are willing and informed contributors to the study.

Another important ethical consideration is maintaining confidentiality and anonymity (Fink, 2005). The researcher must protect participants' personal information and ensure that data is collected and stored securely. This is particularly important when dealing with sensitive topics or vulnerable populations. By respecting participants' privacy, the researcher can create a safe and trustworthy environment for data

collection. Additionally, the researcher should be mindful of potential power dynamics and ensure that participants are not coerced or exploited in any way.

The researcher should also strive to minimize potential harm and maximize benefits for participants. This might involve being sensitive to local cultural norms and values, avoiding unnecessary disruptions to participants' daily lives, and ensuring that the research contributes to the betterment of the community. By prioritizing ethical considerations, the researcher can conduct a study that is not only rigorous and informative but also respectful and responsible. This approach will help build trust between the researcher and the community, ultimately contributing to more accurate and meaningful findings (Singer, 2003).

3.12 SUMMARY

This chapter examines the relationship between water quality and climate change in 4 villages, highlighting the impacts of climate variability on water resources. Each village faces unique water quality issues, such as increased bacterial contamination, turbidity, or decreased water tables, linked to climate change. The reliability of observations is crucial, and factors like data quality, sampling frequency, and observer variability must be considered. The chapter emphasizes the need for climate-resilient water management strategies, community education, and targeted interventions to address the specific water quality challenges in each village.

CHAPTER 4

DATA PRESENTATION, INTERPRETATION AND ANALYSIS

4.0 Introduction

This chapter provides a comprehensive presentation, interpretation, and analysis of the data gathered from rural communities within Bindura District, specifically from the wards of Manhenga, Nyava, and Musana. The purpose is to address the research objectives by examining both qualitative insights from participant interviews and quantitative data obtained through structured questionnaires. The mixed-methods approach allows for a triangulated understanding of water quality challenges, usage patterns, and health implications, especially in the context of climate change impacts. Emphasis is placed on demographic variables such as gender, age, and education, which influence community vulnerability and adaptive capacities. Structuring the chapter around key themes aligned with the objectives, the analysis links community experiences with empirical evidence, providing a robust foundation for the subsequent discussion and recommendations.

4.1 Response Rate

Table 1: Response Rates on Data Collection Instruments

Research Instrument	Administered/ Scheduled	Returned/Conducted	%
Questionnaire	40	40	100

Source: Primary data

During the fieldwork, 40 questionnaires were distributed evenly across the three wards of Manhenga, Nyava, and Musana, with all questionnaires returned, representing a perfect 100% response rate. This exceptional return rate is noteworthy given the challenges often associated with rural data collection, such as limited literacy levels and logistical difficulties. The complete response enhances the reliability and representativeness of the findings. High response rates such as this

reduce sampling bias and increase confidence in the statistical analyses, supporting the validity of conclusions drawn (Ali et al., 2021).

The effective administration of questionnaires was facilitated by prior community engagement and the assistance of local guides, which likely encouraged participant cooperation. This reflects the importance of trust and rapport in conducting research within rural settings and aligns with best practices in participatory research methodologies.

4.2 DEMOGRAPHIC DATA

This section presents an analysis of the demographic characteristics of the study population in Manhenga, Nyava and Musana Bindura. The characteristics are presented below, focusing on three key aspects, gender distribution, educational levels and age of respondents.

4.2.1 Gender Distribution of Participants

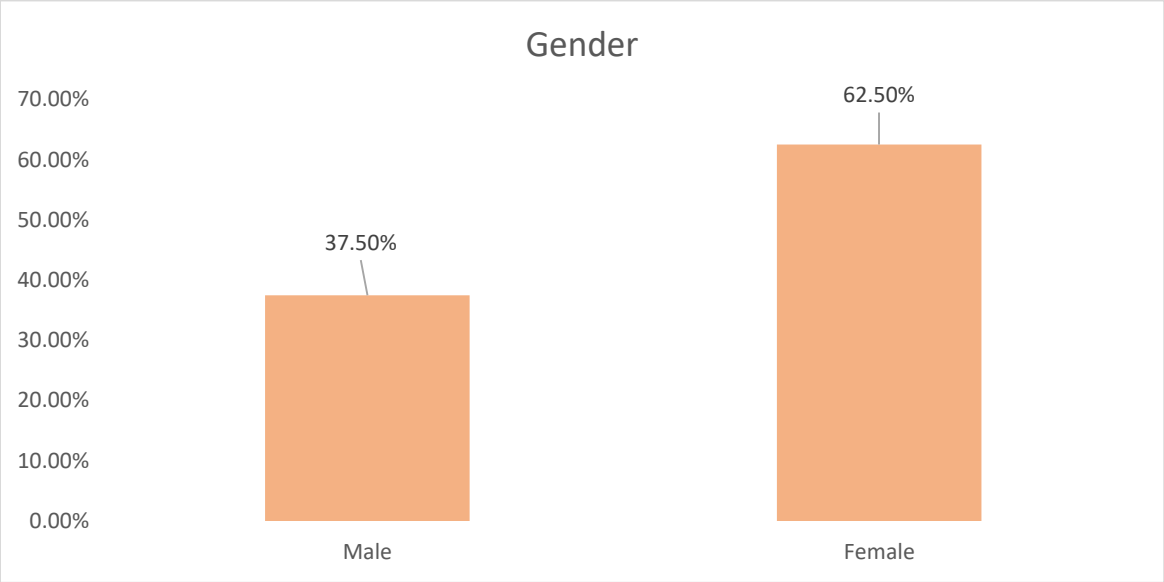

Figure 1: Gender distribution of participants

Fig 1 above shows the gender distribution of the participants was recorded in order to be able to understand sustainability in terms of gender ratios in the survey and results

show that there were more women than men who participated in the survey the total being 37.5% and 62.5% respectively.

Quantitatively, women constitute 62.5% of respondents, while men make up 37.5%. This gender disparity is consistent with rural Zimbabwean social structures, where women predominantly manage water collection, storage, and usage in the household (UN Women, 2018). The data suggest that women are disproportionately affected by water quality and availability challenges.

Generally, women are affected, this gender imbalance has significant implications for vulnerability assessments and intervention strategies. Women's central role in water management means they are more exposed to health risks from poor water quality and bear greater labor burdens during scarcity. Consequently, policies and programs should prioritize women's participation and leadership in water resource planning and climate adaptation initiatives.

4.2.2 Educational Levels of Respondents

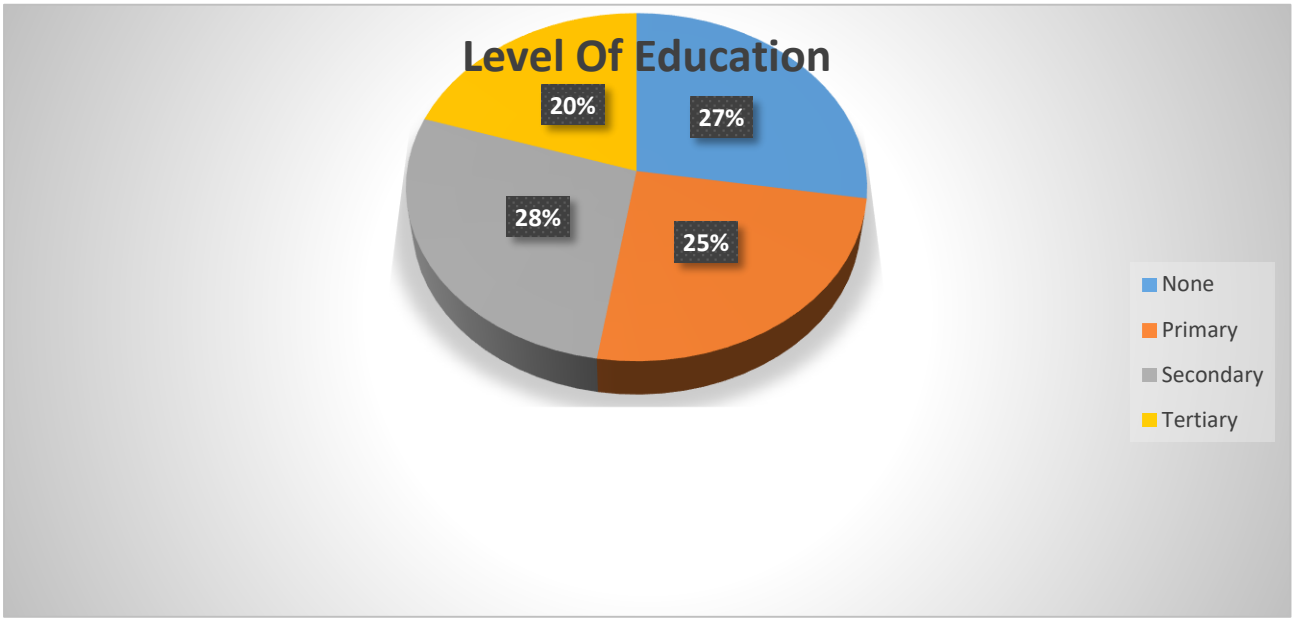

Figure 2: Level of Education

The participants' levels of education were also studied. Almost half of the population (27 and 25) have not attained basic education which can impact water availability negatively. The lack of education in Bindura has significant implications for water availability and perceptions. Without basic education, residents may not fully

comprehend proper water management techniques, leading to inefficient use and potential waste of this vital resource, thus they rely on traditional ways of water conservation. Moreover, limited knowledge about waterborne diseases can make residents more vulnerable to health risks associated with contaminated water. According to a study by Tumwine et al. (2002), education plays a crucial role in promoting safe water handling practices and reducing the risk of waterborne diseases.

The data reveal diverse educational attainment among respondents. While 28% reached secondary education and 20% attained tertiary education, a significant portion had only primary education or no formal schooling. This educational profile indicates a mixed capacity for understanding and implementing improved water management practices.

The study found out that most of the respondents who participated in this study attended school, though they had attained different levels of qualifications. These educational outcomes indicate that the majority (28%) of those who took part in the survey had secondary as their highest level of education and those with tertiary were had 20%.

Lower education levels can limit comprehension of water contamination risks and reduce adoption of health-promoting behaviors. Conversely, the presence of tertiary-educated individuals, though fewer, suggests potential community knowledge hubs that could be leveraged for awareness campaigns. Therefore, tailored education programs must consider literacy levels and utilize accessible communication methods.

Furthermore, the lack of education can limit residents' ability to participate in decision-making processes related to water management, making it challenging for them to influence decisions affecting their water supply. community engagement and education are essential for promoting environmental protection and sustainable water management practices. Research has shown that educated individuals are more likely to adopt sustainable water management practices and have better perceptions of water quality (Smith et al., 2015). Therefore, investing in education is crucial for promoting water conservation and management in Bindura.

4.2. Age of Respondents

The age of respondents in this study ranges from 18 to 65 years old, with the majority (55%) falling within the 25-54 years age.

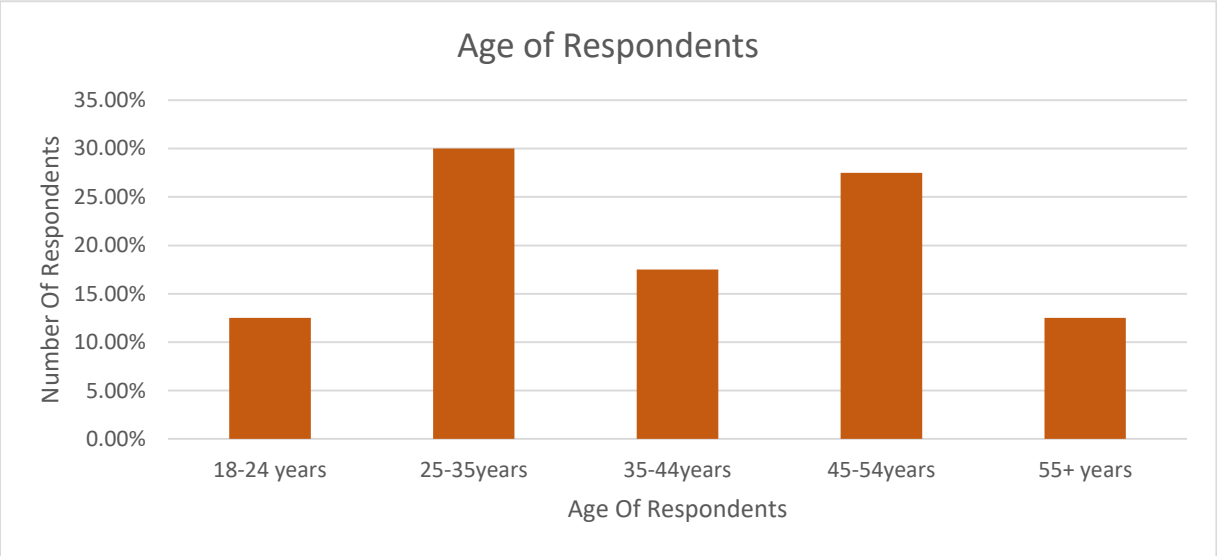

Figure 3: Age of Respondents

The bar graph above shows the age of respondents of people in their numbers, Age distribution data show that middle-aged (25-35 years) adults constitute the largest demographic responsible for water management in households followed by (45-54 years). This group's experience and decision-making power are critical for adopting or resisting changes in water usage practices.

Middle-aged individuals, particularly women, play a crucial role in decision-making regarding water use in families. This highlights the importance of targeting this demographic in water-related interventions and education programs,

.

Women play a vital role in managing water resources within households, undertaking tasks such as fetching water, cleaning and maintaining storage containers, and using

water for cooking, cleaning, and hygiene. According to Cleaver and Hamada (2010), women's involvement in water management is crucial due to their daily responsibilities and intimate knowledge of household water needs. Their participation is essential for designing and implementing effective and sustainable water management practices. As noted by Regmi and Fawcett (1999), women's roles in water management are often overlooked, yet their contributions are vital for household water security

4.3 THEMES AND SUB THEMES

This chapter presents the findings of the study on the impacts of climate change on water quality in Bindura District, Zimbabwe. The chapter is organized around four major themes that emerged from the data analysis. These are,

1. Impacts of Climate Change on Water Quality,
2. Vulnerability of Rural Communities,
3. Environmental and Geological Factors Contributing to Water Shortage, and
4. Adaptation Strategies for Improving Water Quality Management

4.3.1 THE IMPACTS OF CLIMATE CHANGE ON WATER QUALITY

Climate change is a pressing global issue, with far-reaching consequences for human health, livelihoods, and the environment (IPCC, 2021). As noted by the Intergovernmental Panel on Climate Change (IPCC), climate change is likely to have significant impacts on water resources, including changes in water quality and quantity (IPCC, 2014). This theme explores the impacts of climate change on water quality, highlighting the experiences and perceptions of local communities.

The theme, expresses the ways in which climate change affects the quality of water resources, including surface and groundwater. According to Kundzewicz et al. (2007), climate change is expected to alter the hydrological cycle, leading to changes in water quality and quantity.

The main findings under this theme reveal that climate change is perceived to be affecting water quality in the Bindura rural areas, with participants reporting changes in water temperature, turbidity, and contamination. Bates et al. (2008), notes that climate change is likely to increase the frequency and severity of water quality problems. The implications of these findings are significant, highlighting the need for adaptive strategies to mitigate the impacts of climate change on water quality (Adger et al., 2005). The two sub themes derived from the findings are discussed in the subsequent sections.

1. High Temperatures Experienced

High temperatures are a significant consequence of climate change, with profound impacts on water quality in Manhenga. According to Kundzewicz et al. (2007), climate change is projected to alter the hydrological cycle, leading to changes in water temperature, chemistry, and quality. Rising temperatures increase the rate of evaporation from water bodies, leading to reduced water levels and altered water chemistry (IPCC, 2021). This can lead to an increase in algal blooms, which can deplete the oxygen in the water, making it unsuitable for human consumption and aquatic life (Paerl & Huisman, 2008). Furthermore, high temperatures can also increase the growth of bacteria and other microorganisms, posing a significant risk to human health (WHO, 2019)

This was derived from responses in the questionnaires and observations, one participant added that, temperatures have gradually increased which is impacting water bodies in Nyava.

'R*ecently temperatures have increased, causing rivers to dry up and wells dry up around June and July' (female, Nyava)*

Also, another participant from Manhenga supported the same perception of high temperatures being experienced.

'*Livestock have died due to pastures drying up, as a result of a change in rainfall patterns" (male, Manhenga"*

The impacts of high temperatures in rural areas are multifaceted, affecting various aspects of life and livelihood. According to a study, rural residents, especially those in poorer households, struggle with heat stress due to inadequate coping strategies (Klein et al., 2019). Indoor temperatures in houses with tin roofs can be higher than those with cement roofs, making it uncomfortable for occupants.

The effects of high temperatures are further exacerbated by environmental changes such as rivers drying up, pastures drying, and wells drying. Rivers drying up can have severe consequences on agriculture, livestock, and human consumption, leading to food and water insecurity (Molden, 2007). Pastures drying up can devastate livestock production, affecting the livelihoods of rural communities that depend on animal husbandry (Thornton et al., 2009). Wells drying up can lead to acute water shortages, forcing communities to search for alternative sources, often leading to increased walking distances and water-related conflicts (Calow et al., 2011)

Limited access to cooling options in the rural ares is a significant challenge in rural areas. Unlike urban areas, rural areas often lack access to cooling options, making it difficult for residents to mitigate the effects of heatwaves (Harlan et al., 2006) . This can exacerbate heat-related illnesses and other health issues. Socioeconomic challenges also play a crucial role, as rural residents, particularly in low-income households, face difficulties in adopting effective coping strategies against heat stress (Luber & McGeehin, 2008

2. Changes in Water Levels

Climate change is altering the earth's water cycle, impacting water levels through increased evaporation, changing precipitation patterns. Rising temperatures are causing more water to evaporate, leading to droughts and water scarcity in dams and rivers in Musana and Nyava, while others experience intense rainfall and flooding. This was supported by one participant from Nyava,

‘*During the rainy season, borehole water is clean and abundant, unlike during the winter season, when water levels are diminished’ (male Nyava)*

Changes in water levels are another significant impact of climate change on water quality in Bindura District. According to the IPCC (2021), "climate change is projected to alter precipitation patterns, leading to more frequent and severe droughts and floods" (p. 15). Altered precipitation patterns affect the water levels in rivers, lakes, and reservoirs, leading to reduced water quality and increased competition for this limited resource (Gleick, 2003). During droughts, water levels drop, leading to increased concentrations of pollutants and reduced water quality (Molden, 2007). Conversely, floods can lead to overflow and contamination of water sources, posing a risk to human health (WHO, 2019). Changes in water levels can also impact the aquatic ecosystem, affecting the habitats and distribution of aquatic species (Dudgeon et al., 2006). understanding the impacts of climate change on water levels is crucial for developing effective strategies to manage

3. Lack of access to clean water sources,

Access to clean water is a significant challenge in Musana and Nyava, rural where communities face water access challenges due to inadequate sources. Residents often travel long distances to fetch water from contaminated sources, increasing the risk of waterborne diseases like diarrhea, cholera, and typhoid fever. The situation is exacerbated by climate change, which affects water availability and quality, further straining existing resources and impacting the health, economic, and social well-being of the community.

One participant noted that, they usually travel long distances to fetch water,

‘*we travel about 3 km to fetch water for domestic purposes, like cooking and drinking, usually people use river water for washing and irrigating, but these days the rivers are dry’ (*female Musana)

The lack of access to clean water is a critical issue affecting rural communities in Bindura District. According to the World Health Organization (2019), access to safe drinking water is a fundamental human right and essential for good health. Many communities in the district rely on untreated water sources, such as rivers, streams, and shallow wells, which are often contaminated with bacteria, viruses, and other pollutants (Howard et al., 2006). Climate change exacerbates this issue by altering

precipitation patterns, increasing the frequency of droughts and floods, and contaminating water sources (IPCC, 2021). This has severe consequences for rural communities, including poor health outcomes, reduced productivity, and limited economic opportunities. Women and children are disproportionately affected, as they are typically responsible for collecting water for household use, leading to increased workloads and reduced time for education and economic activities (Crow & McCarthy, 2013). Addressing the lack of food insecurity and water scarcity is also a significant concern, affecting human health, agriculture, and ecosystems (Gleick, 2003). To address this issue, climate-resilient water management practices, such as water harvesting and conservation, can be implemented to reduce vulnerability to climate-related shocks (Molden, 2007). References: Gleick (2003); Howard et al. (2006); IPCC (2021); Molden (2007); WHO (2019).

4.3.2 VULNERABILITY OF RURAL COMMUNITIES

Communities experiencing water shortages in Bindura are vulnerable to various challenges, including health risks from waterborne diseases and dehydration, food insecurity due to reduced agricultural productivity and livestock deaths, economic impacts from loss of income and livelihoods, and social impacts such as increased workload and limited access to education. water scarcity can also lead to conflict and migration, as well as environmental degradation. These vulnerabilities disproportionately affect women and children, who often bear the responsibility of fetching water from distant sources, further exacerbating existing social and economic inequalities. To clearly discuss how vulnerable rural communities are, it is crucial to discuss the main uses of water in these places. The main uses of water are presented below,

Main Uses of Water in Districts

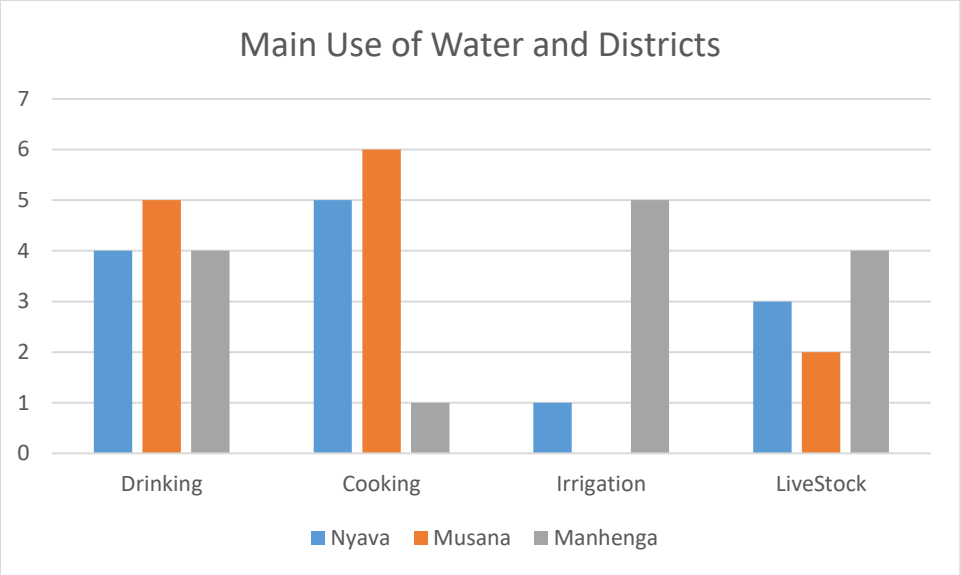

Figure 4: Main Use of Water and Districts

The data indicate that cooking and drinking are the primary uses of water in most households across the three districts. In Nyava**,** the most common use was cooking (5), followed by drinking (4), livestock (3), and irrigation (1). Similarly, in Musana**,** cooking (6) and drinking (5) were the leading uses, with fewer respondents indicating water use for livestock (2) and none for irrigation**.** In contrast, Manhenga showed a different pattern: the highest number of respondents used water for **i**rrigation (5) and livestock (4), while fewer used it for drinking (4) and only one for cooking**.** Overall**,** drinking water was reported by 13 households, cooking by 12, livestock by 9, and irrigation by 6.

This distribution shows variation in water use priorities across districts, with Nyava and Musana focusing on domestic uses, while Manhenga had a stronger focus on agricultural-related uses**.**

This highlights the significant role of agriculture in Manhenga, with water being used primarily for irrigation and livestock. This is consistent with research that suggests agriculture is a major user of water resources globally (Rosegrant et al., 2002).

"In Manhenga, most families use water for irrigation and livestock because farming is our main livelihood." — Participant MMn01 (Male, Manhenga)

Consequently, this highlights the primary use of water in Nyava for domestic purposes, such as cooking and drinking.

“Here in Nyava, water is mainly for cooking and drinking, as most people are not farmers.” — Participant FNv01 (Female, Nyava)

In Musana, people use water mostly for domestic use, but some also keep animals, highlights the mixed use of water in Musana, with a primary focus on domestic use and some use for animal husbandry.

“In Musana, people use water mostly for domestic use, but some also keep animals.” — Participant FMs02 (Female, Musana)

Similarly, Livestock and irrigation water use is common in Manhenga, unlike other areas, reinforces the significance of agriculture and livestock in Manhenga, highlighting the unique water use patterns in this area.

“Livestock and irrigation water use is common in Manhenga, unlike other areas.” — Participant MMn02 (Male, Manhenga)

The data indicate that cooking and drinking are the primary water uses in Nyava and Musana, whereas Manhenga residents rely more heavily on water for irrigation and livestock. This aligns with the wards’ differing economic activities and ecological contexts. The predominance of agricultural water use in Manhenga highlights increased pressure on local water sources, which may affect availability and quality for domestic uses. This underscores the need for integrated water resource management that balances household and agricultural demands.

Climate change can impact water quality, affecting both human health and animal welfare. According to the IPCC (2021), "climate change is projected to have significant impacts on water resources, including changes in water quality and quantity. This highlights the need for adaptive water management strategies to mitigate the impacts of climate change on water resources. Additionally, Climate change can have substantial impacts on water availability and quality in Manhenga, given its reliance on water for agriculture and livestock. According to the IPCC (2021), climate change is projected to have significant impacts on agricultural productivity and food security, particularly in areas with limited water resources. This

highlights the need for adaptive water management strategies to mitigate the impacts of climate change on water resources.

1. Health problems

In Manhenga, the water shortage has had devastating health consequences, with some residents succumbing to cholera due to contaminated water sources. According to recent reports, the cholera outbreak has claimed several lives, with many more at risk due to the ongoing water crisis. Others are experiencing severe headaches and dehydration from inadequate access to clean drinking water, with some cases requiring hospitalization. Furthermore, the community is struggling with food insecurity, leading to malnutrition and related health issues, particularly among children and the elderly. The situation highlights the urgent need for improved access to clean water, sanitation, and food security to prevent further loss of life and alleviate suffering. The lack of access to healthcare services in the area exacerbates the situation, making it difficult for those affected to receive timely medical attention.

The situation in Manhenga is dire, with water scarcity leading to a cholera outbreak that has claimed lives and put many more at risk. According to Howard et al. (2020), cholera outbreaks are often linked to contaminated water sources, highlighting the need for improved water treatment and sanitation infrastructure. Residents are struggling with dehydration, severe headaches, and malnutrition due to food insecurity, particularly affecting children and the elderly. As noted by Black et al. (2019), food insecurity can have devastating impacts on child health and development, including increased risk of malnutrition and related health issues. The lack of access to healthcare services in the area exacerbates the situation, making timely medical attention difficult to obtain. According to a report by the World Health Organization (2020), access to healthcare is a critical factor in reducing mortality rates from water-borne diseases like cholera. Urgent action is needed to improve access to clean water, sanitation, and food security to prevent further loss of life and alleviate suffering.

2. Economic problems

The water shortage in the area can have severe economic implications, particularly for the agricultural sector. Reduced crop yields and crop damage can lead to decreased agricultural productivity, resulting in economic losses for farmers and related industries. This can also lead to increased food prices, reduced access to nutritious food, and decreased economic opportunities, particularly for vulnerable populations. The impact on agriculture can also have a ripple effect on the entire economy, leading to reduced economic growth and increased poverty.

This was supported by a participant from Manhenga, pointing out poverty rates in the society and some people cannot afford paying school fees for their children.

'*This year I have failed to pay school fees for my 3 children because all the rivers we rely on for irrigation are dry*'. (female, Manhenga)

Most people rely on market gardening in Manhenga and the water scarcity has had a devastating impact on the local economy and food security, with many residents struggling to afford basic necessities. As a result, some people are only able to afford one meal per day, leading to widespread malnutrition and food insecurity. This situation is particularly dire for vulnerable populations, such as children, the elderly, and those with pre-existing medical conditions, who require adequate nutrition to maintain their health and well-being. The lack of access to sufficient food can exacerbate existing health problems, leading to a cycle of poverty and malnutrition that is difficult to break.

Prior to the above mentioned statement, another participant from Nyava supported the same idea,

'*These days we are no longer having 3 meals per day, we can only afford a peal per day, just for survival*.' (Female Nyava)

The impact of water scarcity can also be felt beyond agriculture, with businesses that rely heavily on water, such as manufacturing and food processing, facing disruption and increased operational costs. This can lead to reduced competitiveness, potential

business migration, and job losses, further straining the local economy. Additionally, the increased healthcare costs associated with water-borne diseases can place an additional burden on local economies, highlighting the need for effective water management strategies to mitigate these economic problems. Implementing water-saving technologies, improving water infrastructure, and promoting water-efficient practices can help reduce the economic impacts of water scarcity.

4.3.4 The impact of aquifer Characteristics

Observations supports the same theme that, the aquifer characteristics in Manhenga play a crucial role in determining the availability and quality of groundwater resources. According to research, the district's aquifers are primarily composed of granitic and metamorphic rocks, which have varying levels of permeability and storage capacity. Understanding the aquifer characteristics is essential for managing groundwater resources sustainably, particularly in areas where surface water sources are scarce or unreliable. The aquifers in Manhenga are vulnerable to contamination from agricultural activities, poor waste management practices, and climate change.

Manhenga, the presence of a hard-uniform rock formation poses significant challenges to accessing groundwater. According to a study by MacDonald et al. (2012), hard rock aquifers can be particularly difficult to develop due to their low storage and transmissivity. The rock's impermeable nature makes it difficult to drill wells and boreholes, hindering the development of reliable water sources. Furthermore, existing wells that are not deep enough to penetrate through the rock formation are prone to drying up, exacerbating the water scarcity crisis. As noted by Taylor et al. (2013), the success of borehole drilling in hard rock areas depends on identifying suitable fracture zones that can yield sufficient water. This geological constraint necessitates specialized drilling equipment and techniques, increasing the cost and complexity of well construction. As a result, residents are left struggling to access clean and reliable water, highlighting the need for innovative solutions to overcome these geological challenges and ensure sustainable water access for the community.

As noted by Morris et al. (2003), "groundwater vulnerability to contamination is a critical issue in many parts of the world, particularly in areas with shallow water tables or permeable aquifers." In Manhenga, the risk of contamination is exacerbated by the presence of agricultural activities and poor waste management practices, which can lead to the introduction of pollutants into the aquifer. Studies have shown that the hydro-chemical characteristics of groundwater in granitic and metamorphic rock aquifers can be influenced by a range of factors, including rock type, recharge rate, and land use practices (WRC, 2017). In Manhenga, research has highlighted the importance of understanding the local hydrogeology and aquifer characteristics to manage groundwater resources effectively (Makonese, 2017).

1. Urbanization

Urbanization is a significant factor contributing to environmental degradation and increased pressure on water resources in the rural areas. As the district's population grows, there is a rising demand for housing, infrastructure, and services, leading to increased encroachment on agricultural land and natural habitats.

Urbanization also leads to increased water demand, straining existing water resources and infrastructure as noted by a participant from Manhenga,

'*I have lived for 10 years in this area, since then people are continuously building their houses, and changing the natural environment*' (male, Manhenga)

Furthermore, urban areas in Bindura District often lack adequate waste water treatment facilities, resulting in the discharge of untreated wastewater into water bodies, which can contaminate water sources and pose health risks to communities. Therefore, it is essential to develop sustainable urban planning strategies that balance economic growth with environmental protection and social equity.

2. Land Degradation

Land degradation is a pervasive environmental issue in Manhenga and Nyava, driven by a combination of factors, including deforestation, overgrazing, and poor agricultural practices. The consequences of land degradation are far-reaching,

including reduced agricultural productivity, increased soil erosion, and loss of biodiversity.

One participant indicated that, there is massive degradation of land due to the owning of large heads of cattle,

'*Most settlers here are resettled farmers, who own farms and large heads of cattle*' (male Musana)

This was supported by another participant from Musana, adding that land degradation in Musana is primarily driven by deforestation and overgrazing, which are exacerbated by climate change. The removal of vegetation cover through deforestation and overgrazing leads to soil erosion, loss of fertility, and increased runoff. This not only affects agricultural productivity but also increases the risk of water scarcity and decreased biodiversity. According to Geist and Lambin (2002), deforestation and land degradation are often linked to agricultural expansion and overgrazing, highlighting the need for sustainable land management practices.

'*We rely on wood as a main source of fuel, only a few use gas some are not aware or the other sources of energy like gas and some cannot afford electricity*' (male Musana)

Land degradation also affects water resources, as sedimentation and nutrient runoff can contaminate water bodies and reduce water quality. Furthermore, land degradation can exacerbate poverty and food insecurity, particularly among rural communities that rely heavily on agriculture for their livelihoods. Therefore, it is crucial to implement sustainable land management practices, such as conservation agriculture and reforestation, to restore degraded lands and promote ecosystem resilience in Bindura District.

4.3.4 ADAPTATION STRATEGIES TO IMPROVE WATER QUALITY IN THE RURAL AREAS.

Access to clean water is a fundamental human right, yet many rural communities struggle with water quality issues, posing significant risks to public health and well-

being. In these areas, water sources are often contaminated with pathogens, chemicals, and other pollutants, leading to water-borne diseases and other health problems. To address these challenges, adaptation strategies are essential to improve water quality, ensure sustainable water management, and protect the health and livelihoods of rural communities. This response highlights key adaptation strategies to improve water quality in rural areas, focusing on practical, community-based solutions that can be implemented to enhance water security and promote healthy living.

To understand the strategies needed it is important to discuss the water usage and irrigation practices, as shown below

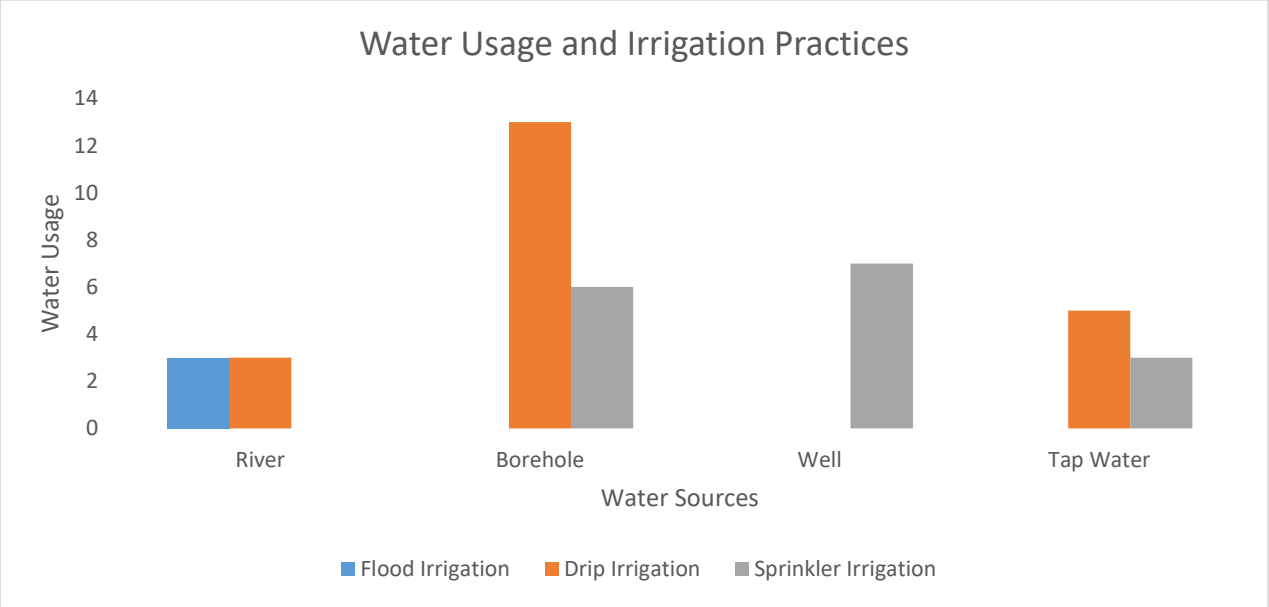

Figure 5: Water Usage and Irrigation Practices

The data show that among the irrigation methods used**,** mainly drip irrigation was used**,** with 21 respondents indicating its use. The majority of these (13) sourced their water from boreholes**,** followed by 5 from tap water and 3 from rivers**.** 16 respondents, most of whom used well water (7), with additional users from boreholes (6) and tap water (3), reported sprinkler irrigation**.** Flood irrigation was the least utilized method, reported by only 3 respondents**,** all of whom sourced their water from rivers**.** No users of boreholes, wells, or tap water reported using flood irrigation. These figures show a clear distribution pattern of irrigation methods in relation to primary water sources, with drip and sprinkler systems dominating**,** and flood irrigation limited to river water users**.**

One participant indicated that they use water saving irrigation techniques.

"Most farmers here use drip irrigation because it saves water, especially when water is scarce." — Participant MMn02 (Male, Manhenga)

In rural areas, rivers often dry up due to changing climate conditions, leaving boreholes as a vital source of water for irrigation. Boreholes can provide a reliable source of water, enabling farmers to maintain crop production and support their livelihoods. However, it's essential to ensure the sustainability of borehole water sources through proper management and conservation practices.

"We mostly use borehole water for irrigation, as river water is not reliable." — Participant FMn01 (Female, Manhenga)

Another indicated that, flood irrigation is a common practice in areas where water is abundant, particularly during rainy seasons or when rivers are flowing. This method involves flooding the entire field with water, which can be beneficial for certain crops.

"Flood irrigation is only possible near rivers, but it wastes a lot of water." — Participant FMs02 (Female, Musana)

The quantitative findings show drip irrigation as the most popular method, particularly among borehole water users. Sprinkler irrigation is also common, predominantly among those relying on wells and taps, whereas flood irrigation is confined to river water users. The preference for water-efficient irrigation methods such as drip and sprinkler systems reflect growing awareness of water scarcity challenges. However, rain water harvesting, growing drought tolerant crops and practicing afforestation can also be done to improve the availability of water.

1. Considering Rain water harvesting

In Musana, communities are adopting rainwater harvesting systems to collect and store rainwater for domestic use, reducing reliance on vulnerable groundwater sources. Additionally, they are implementing conservation agriculture practices, such as mulching and crop rotation, to enhance soil moisture retention and reduce erosion.

These strategies help build resilience to changing precipitation patterns and increased temperatures. One participant supported the idea of rain water harvesting,

'*We have inserted water storage tanks and as a community we are planning to build dams to harvest more water for irrigation*' (male, Musana)

In Musana, communities are proactively adapting to climate variability by adopting innovative rainwater harvesting systems. These systems enable households to collect and store rainwater for domestic use, significantly reducing their reliance on vulnerable groundwater sources. By harnessing rainwater, communities can mitigate the impacts of droughts and groundwater scarcity, ensuring a more reliable source of clean water for drinking, cooking, and hygiene. According to a study by Gould and Nissen-Petersen (2003), rainwater harvesting can provide a sustainable and cost-effective solution for improving water access in rural areas.

In addition to rainwater harvesting, communities in Musana are implementing conservation agriculture practices to enhance soil moisture retention and reduce erosion. Techniques such as mulching and crop rotation help to improve soil health, increase crop yields, and promote more efficient water use. Mulching, for example, reduces soil evaporation and runoff, while crop rotation enhances soil fertility and structure (Kassam et al., 2009) [2]. By adopting these conservation agriculture practices, farmers in Musana can build resilience to changing precipitation patterns and increased temperatures, ultimately improving their agricultural productivity and food security.

The adoption of rainwater harvesting and conservation agriculture practices in Musana demonstrates the potential for community-led adaptation initiatives to enhance climate resilience. By diversifying their water sources and improving soil management, communities can reduce their vulnerability to climate-related shocks and stresses. As noted by Morton (2007), community-based adaptation initiatives can provide a critical foundation for building climate resilience in rural areas. By supporting and scaling up these initiatives, it is possible to promote sustainable development and improve the well-being of vulnerable communities.

2. Growing drought tolerant varieties

In Nyava, local farmers are diversifying their crops to include drought-tolerant varieties, such as sorghum and millet, which can thrive in areas with limited water availability. They are also constructing contour ridges and terracing to reduce soil erosion and improve water retention. Furthermore, community-led water management committees are being established to oversee the equitable distribution of water resources and ensure sustainable use.

'We have recently received drought tolerant varieties from the NGOs as inputs to aid farning in this area'. (female Nyava)

The development and cultivation of drought-tolerant crop varieties is a crucial strategy for adapting to climate change, particularly in regions prone to water scarcity. These crops are bred to thrive in conditions with limited water availability, thereby reducing the need for irrigation and minimizing crop losses due to drought. By cultivating drought-tolerant varieties, farmers can improve crop yields, enhance resilience to extreme weather conditions, and ensure food security despite the challenges posed by climate variability. According to a study by Cattivelli et al. (2008), drought-tolerant crops can maintain higher yields and reduce water usage, making them an attractive option for farmers in water-scarce regions. One participant added that,

'*The education of cross breeding the hard Mashona breed of cattle was well received by the community*, (male, Musana)

The development of drought-tolerant crop and animal varieties involves advanced breeding techniques and genetic engineering. Scientists identify genes that confer drought tolerance and introduce them into crops, enabling them to conserve water and withstand stress. For example, some drought-tolerant crops have deep roots that allow them to access water deeper in the soil, while others have modified photosynthetic pathways that reduce water loss. By adopting these crops, farmers can reduce their reliance on irrigation, lower their water costs, and promote sustainable agriculture practices. As noted by Tuberosa and Salvi (2006), the use of drought-tolerant crops can play a critical role in ensuring food security and adapting to climate change.

3. Afforestation and reforestation

In Manhenga, communities are promoting agroforestry practices, integrating trees into agricultural landscapes to enhance soil health, reduce erosion, and provide shade. They are also implementing efficient irrigation systems, such as drip irrigation, to minimize water waste and optimize water use. Moreover, local schools and health centers are being equipped with solar-powered water systems, providing a reliable source of clean water and reducing dependence on diesel-powered generators. These adaptation strategies are helping to build climate resilience and improve livelihoods in these communities. One participant said that,

"Trees age grown continuously in this community because people here have adopted well the afforestation programmes provided by the agricultural extension officers." — *Participant MMn02* (Male, Manhenga)

Afforestation and reforestation are critical strategies for mitigating climate change, promoting biodiversity, and enhancing ecosystem services. By planting new trees or restoring degraded forests, we can sequester carbon dioxide from the atmosphere, reducing the greenhouse gases that contribute to global warming. According to a study by Bonan (2008), forests play a significant role in the global carbon cycle, and afforestation efforts can help mitigate climate change by removing CO2 from the atmosphere [1]. Additionally, forests provide habitat for a wide range of plant and animal species, support watershed health, and offer numerous ecosystem benefits.

Afforestation and reforestation efforts can also contribute to sustainable development and improve the livelihoods of local communities. By restoring forests, we can enhance soil fertility, reduce erosion, and promote water cycling, ultimately supporting agricultural productivity and food security. As noted by Bullock et al. (2011), reforestation can also provide numerous benefits for local communities, including timber, fuelwood, and non-timber forest products [2]. Furthermore, forests can help regulate the climate, reducing the risk of extreme weather events and promoting ecosystem resilience. By prioritizing afforestation and reforestation, we can promote sustainable development, support biodiversity, and mitigate the impacts of climate change.

4. The indigenous knowledge systems

In Manhenga, traditional weather forecasting methods include observing natural phenomena such as animal behavior, plant indicators, and celestial patterns. For example, changes in bird migration or unusual animal activity can signal impending weather changes, while certain plant species may bloom or change color in response to shifts in weather patterns. Additionally, local communities may observe wind and cloud patterns, as well as traditional seasonal markers, to predict weather conditions. These indigenous knowledge systems are often passed down through generations and can be effective in predicting local weather patterns

Traditional weather forecasting involves using observations of natural phenomena and environmental indicators to predict weather patterns. This approach relies on knowledge passed down through generations, including observing plant behavior, such as blooming or changes in color, monitoring animal behavior, like changes in bird flight patterns or animal activity, tracking changes in wind direction, observing cloud formations, and monitoring temperature and humidity. By paying attention to these indicators, communities can gain valuable insights into upcoming weather patterns, enabling them to prepare for and adapt to changing conditions, ultimately supporting agriculture, food security, and disaster risk reduction.

The effectiveness of traditional weather forecasting lies in its localized nature, allowing communities to develop nuanced understandings of their specific environments. This approach can be particularly valuable in areas where modern meteorological infrastructure is limited or non-existent. By combining traditional knowledge with modern forecasting methods, communities can develop more robust and adaptive weather forecasting systems, enhancing their resilience to climate variability and change. According to a study by Kanyanga et al. (2013), integrating traditional knowledge with modern climate forecasting can improve the accuracy and relevance of weather forecasts for local communities.

5. Awareness and educational campaigns on water quality and climate change

In rural Nyava, communities are receiving training and education to enhance their capacity for sustainable water management. Initiatives include water management training, agricultural extension services, community-based water management, and

capacity building, aiming to improve water security and promote sustainable development

In rural Zimbabwe, various initiatives are underway to reduce water shortages and improve the well-being of communities. One key strategy is the adoption of efficient irrigation systems, such as drip irrigation, which delivers water directly to plant roots, reducing evaporation and runoff (Molden, 2007). This technique helps farmers boost crop yields while minimizing water waste. Additionally, rainwater harvesting systems are being implemented to collect and store rainfall during periods of abundance, supplementing water supply during dry spells.

Also, soil conservation techniques, such as conservation tillage, cover crops, and mulching, are also being used to preserve soil health, retain moisture, and reduce erosion (Kassam et al., 2009). These methods help maintain organic matter content, improve water infiltration rates, and promote sustainable agriculture. Furthermore, drought-resistant crop varieties are being adopted to optimize water use and enhance productivity. Genetic engineering techniques, such as CRISPR/Cas9, are also being explored to develop more resilient crop varieties.

Community-based water management initiatives are also being implemented, with water point committees and pump operators trained to manage and maintain water systems (Hope, 2015). Solar-powered water systems are being promoted as a sustainable and cost-effective solution for rural water supply, reducing reliance on diesel or electricity-powered systems. Educational programs and awareness campaigns are also being conducted to promote water conservation practices, climate-resilient farming, and sustainable water management among rural communities. By adopting these strategies, rural communities in Zimbabwe can improve their water security, enhance agricultural productivity, and promote sustainable development.

4.9 Chapter Summary

This chapter has detailed the key findings on water quality and usage in Manhenga, Nyava, and Musana wards. Through triangulated participant voices and robust quantitative data, the study highlights gendered vulnerabilities, educational and age-

related factors influencing water management, and distinct water use patterns shaped by local livelihoods. Salinity emerges as the principal water quality challenge, exacerbated by climate variability and environmental degradation. Health risks linked to contaminated water sources remain a serious concern. The findings underscore the importance of context-specific, gender-sensitive, and education-informed water management policies to enhance community resilience to climate change impacts. These results will inform the broader discussions and recommendations in Chapter 5.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

The purpose of the study was to provide an in-depth discussion of the findings from the study investigating the impacts of climate change on water quality in Bindura District, the vulnerability of rural communities to these impacts, their coping strategies, and recommendations for sustainable interventions. The discussion was framed around the four main research objectives, linking the empirical data with existing literature to elucidate patterns, implications, and avenues for future action.The previous chapter looked at data presentation, analysis and discussion. This chapter presents summary of the study and conclusions of the study drawn from the research findings. At the end of the chapter are the recommendations of the study.

5.1 Summary of the study

This study investigates the impact of climate change on water quality, a pressing concern given the far-reaching consequences of climate variability on global water resources. The background of the study highlights the significance of understanding the relationship between climate change and water quality, emphasizing the need for informed decision-making and sustainable management of water resources. As climate change continues to alter precipitation patterns, temperature regimes, and weather extremes, its effects on water quality are becoming increasingly evident, with potential implications for human health, ecosystems, and economic development.

The study aims to contribute to the existing body of knowledge on the impact of climate change on water quality by achieving specific objectives. These objectives serve as a guiding framework for the investigation, enabling a comprehensive examination of the complex relationships between climate change and water quality.

5. To investigate the impacts of climate change on water quality in Bindura District.
6. To assess the vulnerability of rural communities in Bindura District to climate change impacts on water quality.
7. To assess other environmental and geological factors that contribute to water shortage in the area.
8. To identify effective adaptation strategies for improving water quality management in Bindura District.

Exploring the impact of climate change on water quality, this study seeks to provide valuable insights that can inform policy and decision-making processes, ultimately supporting the development of effective strategies for managing water resources in a changing climate. Through a thorough analysis of the impact of climate change on water quality, this study endeavors to shed light on the intricate dynamics at play, including the effects of changing precipitation patterns, increased temperatures, and extreme weather events on water quality parameters such as pH, turbidity, and nutrient levels. By examining these relationships, the study aims to provide a nuanced understanding of the challenges posed by climate change to water quality and to identify potential adaptation and mitigation strategies that can help safeguard water resources for future generations.

The study was guided by the Adaptive Capacity Theory suggests that the ability of rural communities to adapt to climate-related changes in water quality is influenced by various factors, including economic resources, social networks, knowledge, and technology. Studies have shown that climate change is exacerbating water pollution in rural communities, particularly in sub-Saharan Africa. Changes in precipitation patterns and increased frequency of floods are contaminating water sources with pollutants and sediments, further compromising water quality

With respect to methodology, the study used pragmatic research, the researcher aim to find solutions to the challenges faced by rural communities in terms of water quality and climate change. This paradigm allows the researcher to focus on what works in practice, rather than adhering to a specific ideology or methodology. By adopting a pragmatic approach, the research can combine multiple methods and approaches to achieve a more comprehensive understanding of the research problem.

To collect data, the researcher first got clearance from his supervisor. The researcher delivered the questionnaires to the respondents and observation guide. Data from questionnaires, interviews and document were analysed. Simple descriptive statistical methods and thematic approach were used to summarise the data.

To ensure trustworthiness and transferability of the research the researcher obtain permission from relevant authorities, organizations, or individuals before conducting research. This is especially important when conducting research on vulnerable populations or in sensitive environments. Participants in research were given the option to remain anonymous, meaning that their identity was not disclosed in any published work or reports. This is important for protecting their privacy and confidentiality.

Collected data was presented, analyzed and discussed guided by the themes derived from the research objectives in chapter one. The following themes were developed:

5. Impacts of Climate Change on Water Quality,
6. Vulnerability of Rural Communities,
7. Environmental and Geological Factors Contributing to Water Shortage, and
8. Adaptation Strategies for Improving Water Quality Management

The study was constrained mainly by time factor and limited financial resources. The researcher tried to plan efficient and execution, he was also flexible and adaptability to minimise these challenges.

5.2 CONCLUSIONS

The research came out with four conclusions. These are:

1. This study explored the multifaceted impacts of climate change on communities, particularly in relation to water resources. Rising temperatures were found to have significant effects on water quality, posing substantial challenges to human health and ecosystem sustainability. The vulnerability of rural communities to diseases and poverty was also exacerbated by climate

change, underscoring the need for effective adaptation and mitigation strategies to support these populations.

2. The characteristics of aquifers and the pace of urbanization were identified as critical factors influencing water availability and quality. Urbanization, in particular, was found to strain existing water resources, highlighting the importance of sustainable water management practices in urban planning. Conversely, the characteristics of aquifers, including their recharge rates and storage capacities, played a crucial role in determining the resilience of water resources to climate change.
3. In response to these challenges, communities and policymakers have employed various adaptation strategies. Water harvesting emerged as a vital approach, enabling communities to conserve and manage water resources more effectively. Additionally, the cultivation of drought-tolerant crop varieties has shown promise in enhancing agricultural resilience to climate change. Afforestation and reforestation efforts have also been recognized for their potential to mitigate the impacts of climate change on water resources, by reducing runoff, improving infiltration, and enhancing groundwater recharge.
4. The study also highlighted the importance of indigenous knowledge systems in developing effective adaptation strategies. By leveraging traditional knowledge and practices, communities can develop context-specific solutions that are tailored to their unique environmental and socio-economic conditions. This approach not only fosters community engagement and ownership but also promotes the preservation of valuable indigenous knowledge. By combining these strategies, communities can build resilience to climate change and ensure the long-term sustainability of their water resources.

5.3 Recommendations

Various recommendations were developed from the findings of this study. These are discussed hereunder.

1. Recommendations to Policy Makers

To effectively address the challenges posed by climate change, policymakers must prioritize adult education and awareness-raising initiatives. By engaging in targeted educational programs, policymakers can empower communities with the knowledge

and skills necessary to adapt to climate change. This includes providing training on climate-resilient practices, water conservation techniques, and sustainable livelihoods. Through investing in adult education, policymakers can foster a culture of climate resilience and promote community-led adaptation initiatives.

Policymakers should also prioritize investments in water infrastructure, including drilling boreholes and constructing dams, to enhance water security and support climate-resilient development. Additionally, policymakers can provide technical and financial assistance to communities to support the adoption of water conservation techniques, such as rainwater harvesting and efficient irrigation systems. By taking a proactive and multi-faceted approach, policymakers can help build the resilience of communities to climate change and support sustainable development.

1. **Recommendation to the residents**

Residents of Bindura rural can adopt various strategies to adapt to climate change and improve water quality. One key approach is to implement water conservation and harvesting practices, such as rainwater harvesting and efficient irrigation methods like drip irrigation. By constructing dams and water tanks, communities can store water for dry periods, ensuring a steady supply for agricultural and domestic needs. Additionally, adopting drought-tolerant crop varieties and conservation agriculture practices like mulching, terracing, and contour farming can help reduce soil erosion, improve soil health, and promote water retention.

Indigenous knowledge systems can also play a crucial role in developing effective climate change adaptation strategies. By integrating traditional knowledge with scientific approaches, communities can develop context-specific solutions that are tailored to their unique environmental and socio-economic conditions. For example, community-based weather forecasting methods, such as observing natural phenomena, can be used to predict weather patterns and inform decision-making. Furthermore, agroforestry practices, which involve integrating trees into agricultural landscapes, can enhance biodiversity, improve soil health, and mitigate the impacts of climate change.

To effectively implement these strategies, community engagement and education are essential. Organizing community workshops and training sessions can raise awareness about climate change, its impacts, and adaptation strategies. Providing training on climate-resilient agriculture, water conservation, and management can enhance

community capacity to adapt to climate change. Collaboration between local communities, researchers, policymakers, and extension services is also critical to develop effective climate change adaptation strategies. By working together, communities can develop and implement policies that support climate-resilient agriculture, water conservation, and management, and provide incentives for communities to adopt climate-friendly practices.

Indigenous knowledge systems can also play a crucial role in developing effective climate change adaptation strategies. By integrating traditional knowledge with scientific approaches, communities can develop context-specific solutions that are tailored to their unique environmental and socio-economic conditions. For example, community-based weather forecasting methods, such as observing natural phenomena, can be used to predict weather patterns and inform decision-making. Furthermore, agroforestry practices, which involve integrating trees into agricultural landscapes, can enhance biodiversity, improve soil health, and mitigate the impacts of climate change.

To effectively implement these strategies, community engagement and education are essential. Organizing community workshops and training sessions can raise awareness about climate change, its impacts, and adaptation strategies. Providing training on climate-resilient agriculture, water conservation, and management can enhance community capacity to adapt to climate change. Collaboration between local communities, researchers, policymakers, and extension services is also critical to develop effective climate change adaptation strategies. By working together, communities can develop and implement policies that support climate-resilient agriculture, water conservation, and management, and provide incentives for communities to adopt climate-friendly practices.

2. **Recommendation to the educational sector**

The educational sector in Zimbabwe should prioritize climate change education by incorporating it as a cross-cutting theme in the syllabus. This would enable students to develop a deeper understanding of climate change, its impacts, and adaptation strategies. By integrating climate change into various subjects, such as science, geography, and social studies, students can gain a comprehensive understanding of the issue and its relevance to their lives. This approach would also foster critical

thinking, problem-solving, and decision-making skills, empowering students to become active contributors to climate change mitigation and adaptation efforts.

In addition to formal education, adult education programs can play a vital role in raising awareness about climate change and promoting adaptation strategies among community members. Community-based education initiatives can target farmers, local leaders, and other stakeholders, providing them with the knowledge and skills necessary to develop climate-resilient practices. By extending climate change education to the broader community, the educational sector can help build a culture of climate resilience and promote sustainable development. This approach would also support the development of community-led adaptation initiatives, enabling communities to take ownership of their climate change responses and develop context-specific solutions.

5. Recommendation to the NGOs

NGOs operating in Zimbabwe should prioritize initiatives that improve water quality, particularly in rural communities. This can be achieved through projects that focus on water treatment, conservation, and harvesting. By providing funding and technical support to communities, NGOs can help develop sustainable water management practices that enhance water security and reduce the impacts of climate change. Additionally, NGOs can support the development of community-led water management initiatives, empowering local communities to take ownership of their water resources and develop context-specific solutions.

NGOs can also provide funding and resources to communities to support climate change adaptation and mitigation efforts. This can include initiatives such as climate-resilient agriculture, afforestation and reforestation, and livelihood diversification. By providing financial support and capacity-building programs, NGOs can help communities develop the skills and knowledge necessary to adapt to climate change and build resilience. Furthermore, NGOs can advocate for policies and practices that support climate change adaptation and mitigation, and hold governments and other stakeholders accountable for their commitments to addressing climate change.

3. Recommendation for further studies

Since the study was limited to Bindura District in one province, there is a need to look at further studies on water quality and climate change in Zimbabwe as a whole, could focus on investigating the impacts of climate change on water resources, including quantifying climate change impacts on water availability, quality, and demand. Research could also identify effective adaptation strategies for managing water resources under climate change, such as water harvesting, conservation, and efficient use. Additionally, studies could examine the role of governance and institutional frameworks in supporting climate-resilient water management, and develop capacity-building programs for water managers, policymakers, and communities. Research could also investigate the interplay between water quality and climate change, including monitoring and assessing water quality in different contexts, and examining the impacts of climate change on water quality.

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Appendix 1

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7616
CEMS DEPT

BINDURA UNIVERSITY OF SCIENCE EDUCATION

Date: --08-- 05--- 2025-

TO WHOM IT MAY CONCERN

NAME: CHINGANGA LOVENESS RUVIMBO REGISTRATION: B2321998B
PROGRAMME: HBSCED GG PART: 2.2

This memo serves to confirm that the above is a bonafide student at Bindura University of Science Education in the Faculty of Science Education.

The student has to undertake research and thereafter present a Research Project in partial fulfillment of the Honors Bachelor of Science Education Geography programme. The research topic is: The impact of climate change on water quality in rural Bindura.

In this regard, the department kindly requests your permission to allow the student to carry out his/her research in your institutions.
Your co-operation and assistance is greatly appreciated.

Thank you

Y MUDAVANHU (PhD)
CHAIRPERSON – CEMS

APENDIX 2

RESEARCH INSTRUMENTS

1. THE QUESTIONNAIRE FOR THE RURAL RESIDENTS OF NYAVA, MUSANA AMD MANHENGA

Introduction

Hello, my name is CHINGANGA LOVENESS, student number B232198B and I am conducting research on climate change and water quality management in rural communities.The research is partial fulfilment of **Honours Degree in Science Education Geography at Bindura university.**The purpose of this questionnaire is to gather information about your experiences and perceptions of water quality, usage, and management in your household and community. With your consent, I would like to record this conversation to ensure accuracy in my notes. Do you have any questions or concerns before we begin?

Questions

SECTION A

DEMOGRAPHIC DATA

What is your age?

_____

2. What is your gender? (Male/Female/Other)

_____

3. What is your highest level of education? (e.g., primary, secondary, tertiary)

_____

4. How many years have you been farming?

_____

5. What is the size of your farm?

_____

6. What type of farm do you have? (e.g., crop, livestock, mixed)

_____

7. What are your main crops/livestock?

_____

8. How many people live in your household?

_____

9. Is farming your primary source of income? (Yes/No)

_____

10. Do you have access to extension services (e.g., agricultural advisors, training)? (Yes/No)

_____

SECTION B

1. What are the primary sources of water for your household, and how do you access them?

_____

_____

2. How do you typically use water in your daily life, and which activities consume the most water?

_____

_____

3. Have you noticed any changes in water availability or quality over time? If so, can you describe them?

4. How would you describe the taste, smell, and appearance of your drinking water?

5. Have you experienced any health issues that you believe are related to water quality? If so, can you describe them?

6. Do you use any water treatment methods, such as boiling or filtering? If so, can you describe your experiences with them?

7. How do you manage water usage in your household, and what strategies do you use to conserve water?

8. Are there any challenges or barriers to implementing water conservation practices in your household or community? If so, can you describe them?

_____

9. Have you noticed any benefits or drawbacks to water conservation efforts in your community? If so, can you describe them?

_____

10. How does your community perceive water quality and management issues, and are there any concerns or priorities that stand out?

_____

11. Are there any environmental factors that affect water quality or availability in your community? If so, can you describe them?

_____

12. Have you observed any changes in water-related behaviors or attitudes within your community over time? If so, can you describe them?

_____

13. What role do you think community involvement plays in water management and conservation, and how can it be encouraged?

_____

14. Are there any local initiatives or programs aimed at improving water quality or management in your community? If so, can you describe them?

_____

15. What do you think are the most pressing water-related issues in your community, and how can they be addressed?

_____

APENDIX 3

2. THE OBSERVATION GUIDE

Objective:

To observe and record the impacts of climate change on water quality in rural areas, focusing on:

1. Water sources and usage
2. Water quality indicators
3. Community adaptation and resilience
4. Environmental factors influencing water quality

Water Sources

and Usage

Water Quality Indicators

Community Adaptation and Resilience

Environmental Factors

- Types of water sources (e.g., rivers, wells, boreholes) - Water collection and storage practices - Water usage patterns (e.g., domestic, agricultural, livestock)	- Physical indicators (e.g., turbidity, color, odor) - Chemical indicators (e.g., presence of contaminants, pH levels) - Biological indicators (e.g., presence of aquatic life)	- Water conservation practices - Climate change awareness and knowledge - Community initiatives and projects related to water management	- Land use practices (e.g., agriculture, deforestation) - Weather patterns and extreme events (e.g., droughts, floods) - Presence of pollution sources (e.g., industrial, agricultural runoff)