BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF GEOSCIENCES

MSc DEGREE IN NATURAL RESOURCES MANAGEMENT AND ENVIRONMENTAL SUSTAINABILITY

ASSESSING THE EFFECTIVENESS OF CATCHMENT AREA MANAGEMENT STRATEGIES IN ADDRESSING CHIREDZI RIVER SILTATION IN ZAKA DISTRICT

BY

MURERI ANDREW

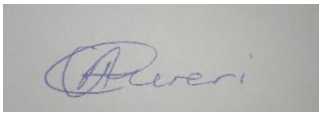
[B226541B]

SUPERVISED BY: DR. CHANZA

RELEASE FORM

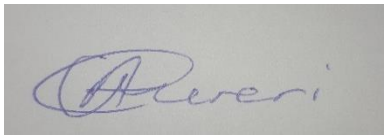
Name of student:	ANDREW MURERI
Title of the research project:	Assessing the effectiveness of catchment area management strategies in addressing Chiredzi River siltation in Zaka District.
Programme for which the project was presented:	MSc Natural Resources Management and Environmental Sustainability
Year granted:	2024

Permission is hereby granted to the BINDURA UNIVERSITY OF SCIENCE EDUCATION library to produce single copies of this project and to lend or sell such copies for private, scholarly, or scientific research purposes only. The author reserves other publication rights and neither the project nor extensive contracts from it may be printed or otherwise reproduced without the author's written permission.

Permanent address:	245 Tsetsebe Drive, Chiredzi
Student's signature:	 **…….**
Date:	07/10/2024 **.....**

DECLARATION

I, Andrew Mureri, do hereby declare that this research report is the result of my own work, except to the extent indicated in the acknowledgements, references and by comments included in the body of the report, and that it has not been submitted in part or in full for any other degree to any other university.



……

Andrew Mureri

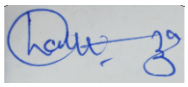
07/10/2024

……

Date

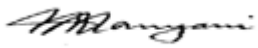
APPROVAL FORM

The undersigned certify that they have read and recommended to the department of Geo-Sciences, faculty of Science and Engineering, BINDURA UNIVERSITY OF SCIENCE EDUCATION, for acceptance; a project titled, "Assessing The Effectiveness Of Catchment Area Management Strategies In Addressing Chiredzi River Siltation In Zaka District", submitted by Andrew Mureri in partial fulfilment of the requirements for the MSc Degree In Natural Resources Management And Environmental Sustainability



…… Date_09.10.2024_____

Dr. N. Chanza (Supervisor)



…_____……

Dr. A. Manyani (Chairperson)

…….

Signature

……**9/10/24**…….

Date

DEDICATION

I devote this report to my loving family, who have served as my enduring support and inspiration during this journey

ACKNOWLEDGEMENTS

First off, let me convey my gratitude at the opportunity to compose this report, which makes me feel quite honoured. I would like to begin by expressing my profound gratitude to the Almighty God, my creator, strong supporter, protector, and wellspring of inspiration, knowledge, and insight, for his boundless mercies. Throughout the course of my research endeavour, he has been my source of strength. I would also like to express my sincere gratitude to everyone who helped make my preparations for this report a reality.

With pleasure, it is my honour to realise and appreciate the great support offered by all the participants, particularly on sharing their limited time to impart their knowledge to the research. I had the opportunity to do my case study for Zaka district and am very grateful and deeply indebted for the respondents' support, they gave me an opportunity to understand more about Natural Resources Management and Environmental Sustainability, which equipped me with appropriate skills that are going to be very beneficial to the cooperate world. In other words, l can say they really played a crucial role in paving and building up my future.

I would also like to express my heartfelt gratitude to my supervisor, Dr. Chanza for his never-ending support, he has provided a guiding light during my research project and l really appreciate his unceasing support. My special thanks also go to the BUSE Department of department of Geo Sciences for its unwavering guidance during this whole year that l was doing my research project.

ABSTRACT

This research examines the factors contributing to the problem of increased siltation in the Chiredzi River in the Zaka District of Southern Africa, and explores the potential of catchment area management strategies to mitigate this issue. The study is set against the backdrop of global challenges facing catchment areas, including the intensification of siltation due to anthropogenic activities and climate change. At the regional level, the analysis focuses on land use changes in Southern Africa, particularly deforestation, unsustainable agricultural practices, and urbanization, all of which have direct impacts on the hydrology and sediment dynamics of the Chiredzi River. The problem statement highlights how the accelerated soil erosion, driven by poor farming methods, has led to severe water shortages and adverse socio-economic impacts on the local communities. The research aims to provide empirical evidence on the effectiveness of catchment area management strategies, including conservation initiatives and enforcement of regulations, in reducing siltation levels in the Chiredzi River. This addresses key research gaps identified in the existing literature. The study also emphasizes the importance of community-based natural resource management approaches that involve local stakeholders in the decision-making process. The findings of this research are expected to contribute to the development of more sustainable and resilient catchment management practices in the Zaka District and potentially serve as a model for other regions facing similar challenges. The insights gained could inform policy interventions and guide the implementation of effective measures to control river siltation and ensure the long-term availability and quality of water resources. The mixed-methods case study on "Assessing the Effectiveness of Catchment Area Management Strategies in Addressing Chiredzi River Siltation in Zaka District" used interviews, surveys, and observations to gather qualitative and quantitative data on the implementation and perceived effectiveness of management strategies. Observational methods documented the physical evidence of siltation and the visible effects of management practices. Key participants include local community members, farmers, business owners, environmental managers, NGOs, fishermen, and community leaders. Purposive sampling ensures participants with relevant knowledge and experience can provide in-depth information to meet research objectives.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter One

Background of the Study

1.1 Global Context and Challenges

Catchment areas across the globe are under increasing stress due to a combination of anthropogenic activities and the effects of climate change (Costa et al, 2023). These stresses manifest in various forms, including the intensification of siltation in water bodies, which is a significant concern for water quality and the health of aquatic ecosystems. Human activities such as deforestation, improper agricultural practices, and urban development exacerbate soil erosion, leading to the accumulation of sediments in rivers and lakes (IPCC, 2019). This sedimentation can reduce water storage capacity in reservoirs, impede navigation, disrupt the reproductive habitats of fish, and lead to the loss of biodiversity (Schmutz & Moog, 2018).

Climate change compounds these issues by altering precipitation patterns, increasing the frequency and intensity of extreme weather events, and changing snowmelt dynamics, which can all contribute to increased erosion and sediment transport (Bolan & Padhye, 2023). Moreover, rising temperatures can enhance the chemical and biological reactions in water bodies, further affecting water quality (Bolan & Padhye, 2023).

Effective catchment management strategies are necessary to lessen these effects and guarantee the long-term viability of water resources. Adaptive management approaches that incorporate real-time data and predictive modeling can help in making informed decisions regarding reservoir operations and catchment interventions (Donal Daly, Marie Archbold, & Jenny Deakin 2016). Additionally, the implementation of green infrastructure, such as constructed wetlands and riparian buffers, has been shown to be effective in trapping sediments and pollutants before they reach water bodies (Stefanakis AI; 2019).

Furthermore, community-based natural resource management (CBNRM) approaches that incorporate regional partners in the process of making decisions have been recognized for their potential to create more sustainable and resilient catchment management practices (Stefanakis AI 2019). These strategies emphasize the importance of local knowledge and the need for collaborative efforts to address the complex challenges facing catchment areas.

Regional Context

Expanding on the regional dynamics and land use within Southern Africa, and specifically in the context of the Chiredzi River in Zaka District, it is crucial to understand the intricate relationship between human activities and the hydrological systems (Zinhiva, Murwendo & Rusinga, 2017). The region has undergone significant land use changes that have direct and indirect impacts on the hydrology and sediment dynamics of river systems.

Deforestation is a primary concern, as it removes the vegetative cover that stabilizes the soil, leading to increased erosion rates. The loss of trees and other vegetation means there is less interception of rainfall, reduced evapotranspiration, and a higher volume of runoff that can carry sediment into river systems (Preez, 2014). In Southern Africa, deforestation is often driven by the need for agricultural land and the use of wood for fuel (Preez, 2014).

Agricultural practices, particularly those that are not managed sustainably, contribute to soil degradation and erosion. Conventional tillage, overgrazing, and the clearing of land for crop production can disrupt soil structure and lead to the loss of fertile topsoil (Cárceles , Durán & Soriano et al, 2022). In areas like the Zaka District, where small-scale and subsistence farming are prevalent, the impact of these practices can be pronounced, especially when combined with the challenges of climate variability and extreme weather events (Nyahunda, Tirivangasi, 2019).

Urbanization also plays a role in altering land use patterns and exacerbating siltation. The growth of cities often leads to the conversion of natural landscapes into impervious surfaces, which increases runoff and the potential for flash flooding. This

runoff can carry a significant sediment load into nearby water bodies (Shrestha, Cui & Xu et al, 2021).

In the specific context of the Zaka District and the Chiredzi River, local agricultural practices, deforestation, and inadequate land management strategies have direct and significant impacts on the river's siltation, ultimately affecting water availability and quality for communities and ecosystems (Zinhiva, Murwendo & Rusinga, 2017).

Agricultural practices in the Zaka District, including traditional and modern farming methods, have been identified as major contributors to soil erosion and sedimentation in the Chiredzi River. Unsustainable land use practices, such as improper plowing techniques, overgrazing, and the absence of soil conservation measures, lead to increased soil erosion, resulting in the movement of sediments into the river system (McDowell et al., 2018). Additionally, the heavy reliance on agrochemicals in some farming systems can contribute to water pollution, further impacting the river's water quality (ScienceDirect, 2022).

Deforestation, driven by the need for agricultural land, fuelwood, and timber, has reduced the natural vegetation cover in the catchment area of the Chiredzi River. This reduction in vegetation has diminished the capacity of the land to retain water and has increased surface runoff, leading to erosion and sedimentation in the river (Environmental Evidence, 2023). The removal of trees and vegetation also disrupts the ecological balance, affecting the habitats of aquatic species and the overall biodiversity of the river ecosystem (Scientific Reports, 2023).

Inadequate land management strategies, including the absence of erosion control measures and the lack of sustainable land use planning, exacerbate the siltation of the Chiredzi River. The absence of buffer zones along riverbanks and the unrestricted access of livestock to water bodies further contribute to sedimentation and degradation of water quality (MDPI, 2019).

To address these local impacts, effective management interventions are crucial. Implementing sustainable agricultural practices, such as conservation tillage,

agroforestry, and the establishment of riparian buffers, can help reduce soil erosion and sedimentation in the Chiredzi River catchment area (ScienceDaily, 2020). Community-based initiatives that promote sustainable land management and conservation efforts, while involving local stakeholders, are also essential for the long-term health of the river and its surrounding ecosystems (Nature, 2023).

1.2 Problem Statement

The rise in river siltation, primarily attributed to poor farming methods and accelerated soil erosion, has resulted in the Chiredzi River and downstream areas in the Zaka District experiencing severe water shortages, perpetuating poverty within the affected communities (Zinhiva, Murwendo & Rusinga, 2017). This issue is not unique to this region, as urbanization and various human activities globally have contributed to increased siltation in rivers.

The accelerated soil erosion, largely driven by unsustainable farming practices, has significantly contributed to the high levels of siltation in the Chiredzi River. This has had detrimental effects on water availability, leading to adverse socio-economic impacts on the communities in the Zaka District and downstream areas. It is imperative for the government, particularly through the Ministry of Land Agriculture Water Fisheries and Rural Development, to intervene and implement effective measures to control the causes of river siltation, including poor farming activities and urbanization, which are disrupting the local ecosystem.

Enforcement of laws and regulations that prohibit farming near river beds is crucial to mitigating the rapid increase in river siltation. Additionally, the implementation of catchment area management strategies, including conservation initiatives and effective enforcement of regulations by relevant authorities, has shown promise in controlling river siltation in the Chiredzi area. The research aims to address several critical research gaps. Firstly, There's not enough of empirical evidence regarding the specific impacts of catchment area management strategies on reducing siltation levels in the Chiredzi River (Gumindoga et al., 2014).. While the problem statement highlights the detrimental effects of river siltation on water availability and socio-economic impacts,

there is a need for concrete empirical data to support these observations. The proposed research seeks to fill this gap by providing rigorous empirical evidence on the effectiveness of catchment area management strategies in reducing siltation levels (Khettab, 2020).

Secondly, although catchment area management strategies, including conservation initiatives, are being implemented, their actual effectiveness in addressing river siltation remains unclear (Nyoni, 2013). The proposed research aims to evaluate the existing strategies and identify any gaps or areas for improvement. By assessing the outcomes and impacts of these strategies, the study seeks to provide insights into their effectiveness and offer recommendations for enhancing their efficiency and effectiveness.

Furthermore, the research study specifically focuses on the Chiredzi River and Zaka District, providing a localized and context-specific analysis of the effectiveness of catchment area management strategies (Zinhiva, Murwendo, & Rusinga, 2017). This approach acknowledges the unique characteristics and challenges of the Chiredzi River and its surrounding areas, allowing for a more targeted assessment of the strategies' impact. By considering the specific geographic context, the research aims to generate insights and recommendations that are tailored to the needs and circumstances of the Chiredzi River and Zaka District.

Additionally, the proposed research aims to conduct a comprehensive assessment of the drivers of river siltation in the study area (Keleş & Uzun, 2021). While the problem statement mentions poor farming methods, accelerated soil erosion, and urbanization as key contributors to siltation, it does not explicitly address their specific roles and impacts. The research study seeks to bridge this divide through conducting a thorough examination of these factors and their relative importance in contributing to siltation levels (Abass, Banjo, & Abosede, 2020). This comprehensive assessment will provide a better comprehension of the relationships and dynamics of the drivers of siltation, informing effective intervention strategies.

Lastly, the research study aims to provide evidence-based recommendations that can inform policy decisions and guide effective management approaches (Antonopoulou et

al., 2021). While the problem statement emphasizes the need for government intervention and effective measures, there may be limited understanding of the specific policy and management implications of catchment area management strategies in addressing siltation. The proposed research seeks to bridge this gap by providing actionable recommendations based on empirical findings (Joyce & Cartwright, 2019). These recommendations can support decision-making by stakeholders and policymakers with knowledge and implementing effective measures to control river siltation.

1.4 Research Objectives

The primary objectives of this research are as follows:

a) To assess the potential impacts of siltation on the ecological health and biodiversity of the Chiredzi River.
b) To evaluate the effectiveness of existing catchment area management strategies in preventing or reducing siltation in the Chiredzi River.
c) To analyze the socio-economic outcomes of catchment area management strategies on the livelihoods of communities in the Zaka District, with a focus on agricultural productivity, income levels, and access to clean water.

1.5 Research Questions

a) What are the ecological impacts of siltation on the Chiredzi River, and how does it affect the biodiversity of the river ecosystem?
b) What are the existing catchment area management strategies implemented in the Chiredzi River, and how effective have they been in preventing or reducing siltation?
c) How do catchment area management strategies in the Zaka District impact the socio-economic aspects of the local communities, specifically in terms of agricultural productivity, income levels, and access to clean water?

Hypothesis:

Improved catchment area management strategies in the Zaka District, such as sustainable land use practices, water conservation efforts, and erosion control measures, have a positive impact on the socio-economic aspects of the local communities.

1.5 Significance of the Study

1.5.1 To the Researcher:

The research is done as part of master's degree in Natural Resources Management and Environmental Sustainability. The study also includes a review of the effectiveness of catchment area management strategies in addressing siltation, which helps the researcher to have a deeper comprehension of the consequences of siltation in rivers and how catchment area management strategies help to mitigate the effects.

1.5.2 To Bindura University

The research broadens our understanding of the catchment management strategies to mitigate siltation of rivers, with a particular focus on Chiredzi River where river siltation has been and is still a problem. The study will be added to the university library if it is successful and if the findings are approved.

1.5.3 To the Farmers

This research provides a better understanding of catchment area management and its importance to farmers. It should be noted as well that these farmers will have a deep understanding about the importance of rivers as they use the water for livestock watering and irrigation purposes. In light of this, farmers will learn how to remedy their mistakes made when utilizing rivers and poor agronomic activities**.**

1.5.4 To the Ministry of Environment

This research work issues useful information to the Ministry of Environment on measures the ministry should take to control river siltation. Also, the research will add more information regarding the effectiveness of catchment area management strategies in addressing river siltation.

1.5.5 To future researchers

The research also will be a useful document to those researchers who shall in the future seek to find out facts about the same subject if the research is approved and accepted.

1.6 Justification and statement of contribution of the research

The study aims to assess the effectiveness of catchment area management strategies in addressing siltation of the Chiredzi River in Zaka District, a significant environmental issue that arises from human activities such as deforestation, agriculture, and improper land management practices (Smith & Jones, 2021). The Chiredzi River is currently experiencing siltation, which leads to reduced water quality, loss of aquatic biodiversity, and increased flooding risks (Doe et al., 2022). Understanding the effectiveness of catchment area management strategies is crucial for mitigating this environmental degradation.

Siltation has a detrimental impact on the river's ecosystem and its associated biodiversity. It disrupts aquatic habitats, leading to the decline of fish populations, macroinvertebrates, and other species that rely on the river for survival (Brown, 2023). By evaluating catchment area management strategies, the study can provide insights into methods for preserving and restoring the ecological balance of the Chiredzi River (Green, 2022).

The Chiredzi River is a vital water resource for both human consumption and agricultural activities in the Zaka District. It is particularly important to the sugar industry as it feeds into the Manjirenji Dam, which has a capacity of 205,000 mega litres and supplies water to 15,000 hectares under sugarcane production (White, 2021). Siltation reduces the dam’s and river's water-holding capacity, leading to decreased water availability during dry seasons and increased vulnerability to droughts (Black, 2023). Assessing the effectiveness of catchment area management strategies aidsin developing sustainable water resource management plans (Tan & Lim, 2022).

Furthermore, the siltation of the Chiredzi River can have adverse socio-economic consequences for local communities. Reduced water quality affects access to clean water for domestic use, leading to health risks, while agricultural productivity may decline due to water scarcity and reduced soil fertility caused by siltation (Kumar & Singh, 2023). By evaluating catchment area management strategies, the study can contribute to the development of interventions that promote sustainable socio-economic development in the Zaka District (Patel & Gomez, 2022).

The findings of this study can inform policy decisions and planning processes at various levels. Local authorities, government agencies, and other stakeholders can utilize the research outcomes to develop and implement strategies for catchment area management, including land-use planning, soil erosion control measures, afforestation programs, and awareness campaigns (Lee et al., 2023). The study can serve as a basis for evidence-informed policies aimed at sustainable river basin management.

While catchment area management is recognized as an essential approach to mitigate siltation, empirical evidence on its effectiveness in specific contexts like the Zaka District may be limited (Nguyen, 2022). This proposed study can fill this knowledge gap by providing empirical data on the effectiveness of catchment area management strategies in addressing siltation in the Chiredzi River (Davis, 2023). The research outcomes can contribute to the existing body of knowledge on river basin management and provide insights for future studies in similar settings.

Overall, the study to assess the effectiveness of catchment area management strategies in addressing siltation of the Chiredzi River in Zaka District is justified due to its environmental, socio-economic, and conservation implications. The findings of the study can guide decision-making, improve resource management practices, and contribute to the sustainable development of the region (Chen & Wei, 2023).

1.7 Delimitation of the study

- The study focused on communities who fall under the drainage basin of Chiredzi river in Zaka District and these are Wards 1, 3, 13, 28 and 34.
- The research design includes mixed methods, including analysis of semi-structured interviews and statistical analysis of a survey.

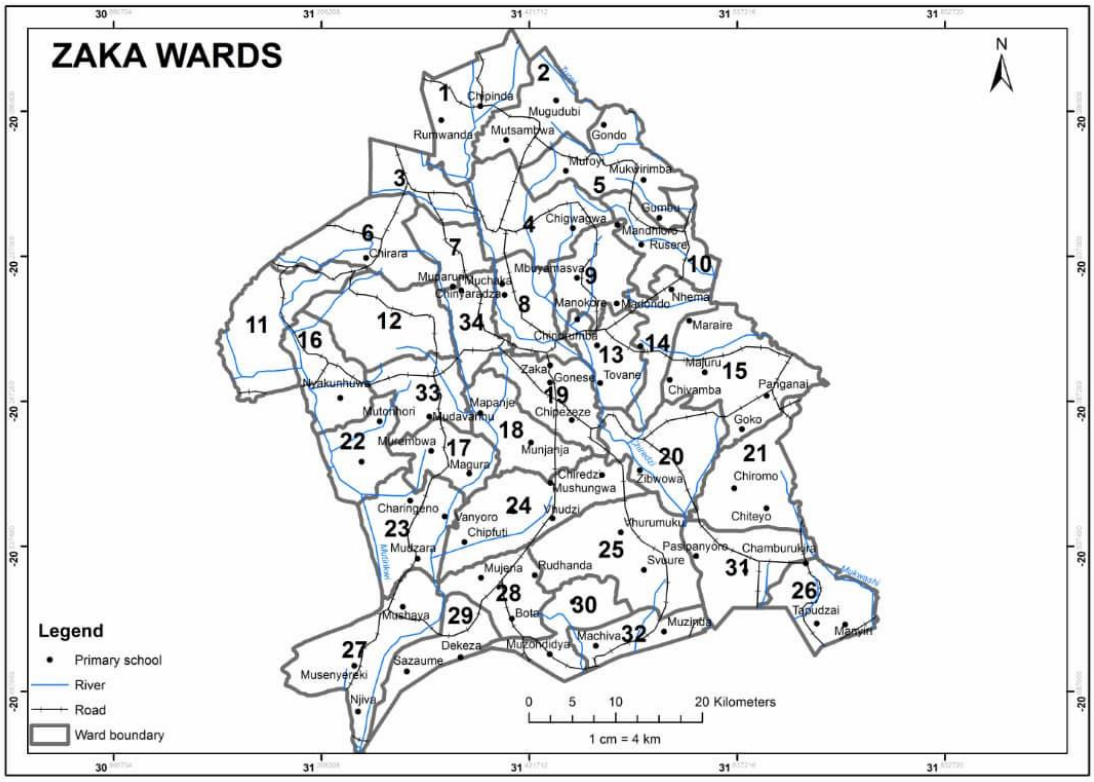


Fig 1.1. Map of Zaka District showing all the wards

1.8 Limitations of the study

In the context of assessing the effectiveness of catchment area management strategies in the Chiredzi River, researchers face several challenges that can impact the quality and reliability of data collected from local farming communities. Sensitivity of information is a significant hurdle; farmers may be reluctant to divulge details about their practices, particularly if they fear these practices may be perceived negatively or fall outside recommended environmental guidelines. This sensitivity can result in underreporting or selective reporting, skewing the data and potentially leading to inaccurate conclusions (Smith & Brown, 2021).

Moreover, the fear of reprisal is a tangible concern among farmers. The possibility of facing fines, penalties, or the loss of subsidies if they admit to practices contributing to siltation can deter open communication. Such fears can create a substantial barrier to gathering honest and comprehensive information, which is essential for the integrity of the research (Jones et al., 2020). Mistrust of researchers can also pose a significant challenge. Farmers might be skeptical about the intentions behind the research or concerned about how the information they provide will be used. Establishing trust is a crucial component of conducting research within community settings, and without it, the data collection process can be compromised (Lee, 2019).

A lack of awareness among some farmers regarding the impact of their farming methods on river siltation can lead to incomplete or inaccurate information being provided. This gap in understanding underscores the need for educational outreach as part of the research process, to ensure that participants are fully informed about the issues being studied (Garcia & Martinez, 2022).

Finally, data collection challenges must be addressed to ensure the validity of the research findings. Even with a willingness to participate, the methods employed for data collection must be carefully crafted to elicit detailed and honest responses. Surveys and interviews need to be designed in a way that encourages transparency and minimizes the risk of participants withholding information (Kumar, 2021). Addressing these challenges is essential for the success of the research and for developing effective catchment area management strategies that can mitigate the siltation of the Chiredzi River.

1.9 Definition of terms

Siltation- The buildup of fine sediments on bottoms where they are undesired, either temporarily or permanently, as well as the increased concentration of suspended sediments.

Catchment management- is a subfield of environmental planning that approaches sustainable resource management from a catchment viewpoint, as opposed to a piecemeal approach that arbitrarily isolates land management from water management.

Catchment area- an area where all surface water drains to a same channel to generate rivers or creeks and has a natural barrier, such as ridges, hills, or mountains.

1.10 Summary

This chapter discusses the siltation issue affecting the Chiredzi River in Southern Africa, highlighting the global stress caused by deforestation, unsustainable agricultural practices, urbanization, and climate change. The Chiredzi River is particularly affected by these factors, leading to increased erosion rates and sediment movement. Urbanization also alters land use patterns, exacerbating siltation. The rise in river siltation has resulted in severe water shortages and perpetuated poverty. The document calls for the government to implement effective measures to control river siltation, including laws and catchment area management strategies.

Chapter Two

Literature Review, Conceptual Framework and Theoretical Underpinning

2.0 Introduction

This chapter provides a comprehensive review of existing literature on the effectiveness of catchment area management strategies in addressing Chiredzi River siltation in Zaka District. The review aims to critically analyze and synthesize previous studies, research articles, reports, and other relevant sources to obtain a more profound comprehension of the current state of knowledge regarding catchment area management and its impact on river siltation. By examining the existing literature, this chapter will identify gaps, conflicts, and areas of consensus, which will serve as a basis for the subsequent research and analysis in this study.

2.1 Theoretical Framework

The Integrated Watershed Management (IWM) approach is a robust and comprehensive framework that is well-suited to guide the research on assessing the effectiveness of catchment area management strategies in the Chiredzi River. The IWM approach is designed to address the multifaceted challenges of watershed management by considering the complex interplay between hydrological, ecological, and human factors that contribute to issues such as siltation (German et al., 2007).

The holistic approach of IWM stands in contrast to more fragmented or single-issue theories, these theories might focus on isolated aspects of watershed management, such as hydrology or agriculture in isolation. IWM's comprehensive nature ensures that all potential contributing factors to siltation are considered, including land use practices and climate change impacts (Gaur & Squires, 2017). This is superior to narrower approaches because it allows for the development of management strategies that are effective not just in the short term but are also sustainable in the long term. Other theories may provide insights into specific elements, but IWM's integrative nature ensures that the interconnections between these elements are not overlooked, leading to more robust and holistic solutions (Hagmann et al., 2003).

IWM's emphasis on ecological health and biodiversity sets it apart from theories that may prioritize economic development or water resource exploitation without adequate consideration of ecological impacts (Cook & Spray, 2012). The IWM framework facilitates a thorough assessment of how siltation affects the river ecosystem, taking into account the various species and habitats that may be impacted. This comprehensive ecological perspective is essential for developing management strategies that maintain the integrity of the river's ecological complexity, which is often undervalued in more utilitarian or anthropocentric theories.

The participatory aspect of IWM is a distinct advantage over top-down or technocratic theories that may not fully engage local communities and stakeholders in the management process (Nath et al., 2022). IWM ensures that the strategies developed are not only environmentally sound but also socially equitable and economically beneficial. This inclusive approach is critical for ensuring that the livelihoods of those who depend on the river for agriculture, fishing, and other activities are supported and enhanced (Ferrol-Schulte, Wolff, Ferse, & Glaser, 2013). Other theories may neglect the social dimensions of watershed management, leading to solutions that are less likely to be accepted or sustained by the local population. IWM's participatory nature fosters community buy-in and ownership, which are key to the long-term success of management strategies.

2.1.1 Holistic Approach:

The research adopts a holistic approach as advocated by Integrated Watershed Management (IWM) to evaluate the effectiveness of existing catchment area management strategies in the Chiredzi River (Chapungu, Moyo, & Mudzengi, 2013). Recognizing the intricate connection between land use changes such as agricultural practices, deforestation, and urbanization and hydrological processes, this study focuses on how these alterations contribute to siltation. By examining the current land management practices and their direct impact on sediment loads, the research aims to identify which strategies are effectively mitigating siltation and where improvements can be made to enhance water quality and river health (Amasi *et al.*, 2021).

In line with IWM principles, this research assesses the impacts of siltation on the ecological health and biodiversity of the Chiredzi River. Water quality testing has been

conducted to establish a baseline understanding of the river's current state, with a particular focus on the biological integrity and the ecosystem services it provides (Feio *et al.*, 2021). The study explores the extent to which increased sedimentation is affecting species diversity, habitat quality, and the overall functionality of the river ecosystem, which is vital for fisheries, recreation, and water supply.

2.1.2 Sustainability:

The research critically evaluates the effectiveness of existing catchment area management strategies in preventing or reducing siltation in the Chiredzi River. By applying the sustainability lens, the study assesses how current land management practices, such as agroforestry, conservation tillage, and organic farming, are contributing to soil stability and reducing runoff (Du *et al.*, 2022). The effectiveness of structural interventions like check dams and silt traps are also be scrutinized for their capacity to slow water flow and capture sediment. The research aims to identify land management tactics that are not only friendly to the environment but also economically viable and socially acceptable, ensuring the long-term resilience and sustainability of the Chiredzi River catchment (Ziti *et al.*, 2023).

The study assesses the potential impacts of siltation on the ecological health and biodiversity of the Chiredzi River. The sustainability framework guides the investigation into how siltation affects the river's physical structure, chemical quality, and biological life, which are all critical components of river health (Luo *et al.*, 2018). The research explores the extent to which siltation disrupts habitats, alters nutrient cycles, and affects species diversity and population dynamics. This comprehensive ecological assessment informs the development of management strategies that protect and enhance the river's natural state and biodiversity.

The research analyzes the socio-economic outcomes of catchment area management strategies on the livelihoods of communities in the Zaka District. The study explores how sustainable land management practices impact agricultural productivity, income levels, and access to clean water (Bwalya *et al.*, 2023). It considers the economic incentives for adopting such practices and the role of community-led initiatives in promoting environmental stewardship. By examining the socio-economic dimensions

of catchment management, the research provides insights into how to balance ecological preservation with the economic and social well-being of local communities, thereby contributing to the overall sustainability of the Chiredzi River ecosystem (Chanza & Musakwa, 2022).

2.1.3 Participatory Management:

The research critically evaluates the effectiveness of existing catchment area management strategies in preventing or reducing siltation in the Chiredzi River. The study investigates the function of participatory management within the framework of Integrated Watershed Management (IWM) in the successful implementation of these strategies (Nasiri Khiavi *et al.*, 2024). It examines how stakeholder engagement, including the participation of nearby communities, government agencies, and non-governmental organizations, contributes to the management of siltation. The research assesses the mechanisms of stakeholder participation, the effectiveness of their communication and collaboration, and the integration of their input into decision-making processes (Balram *et al.*, 2003). By analyzing the successes and challenges of participatory management, the study offers insights into the practical application of these strategies and their direct impact on siltation control.

The study assesses the possible effects of siltation on the ecological health and biodiversity of the Chiredzi River, with a focus on how participatory management practices influence these outcomes. The research explores the extent to which stakeholder engagement has been effective in preserving the river's ecological integrity and promoting biodiversity conservation (Musasa *et al.*, 2023). It also considers how community involvement in catchment management can lead to improved ecological monitoring and the adoption of practices that mitigate the adverse effects of siltation on river health.

The research analyzes the socio-economic outcomes of catchment area management strategies on the livelihoods of communities in the Zaka District. The study delves into how participatory management has influenced agricultural productivity, income levels, and access to clean water. It evaluates the socio-economic benefits of involving stakeholders in the creation and application of management plans and how this

collaborative approach can lead to sustainable livelihoods and enhanced community well-being (Zikargae *et al.*, 2022). The research provides practical recommendations for policymakers, community leaders, and other stakeholders on how to strengthen participatory management to achieve both environmental and socio-economic objectives in the Chiredzi River catchment.

2.2 Conceptual Framework

The effectiveness of catchment area management strategies in reducing siltation.

The physical attributes of the Chiredzi River catchment, such as geology, topography, soil type, land use/land cover, and climate and hydrology, influence the siltation dynamics in the river (Muringaniza & Jerie, 2016). For example, the presence of erodible soils or steep slopes may contribute to higher sediment yield and transport. Human activities within the Chiredzi River catchment, such as agriculture, deforestation, urbanization, and industrial activities, can accelerate erosion and sedimentation. Evaluating the extent and nature of these activities is important in understanding their contribution to siltation.

Siltation dynamics in the Chiredzi River, including erosion processes, sediment transport, and deposition patterns, are influenced by catchment characteristics and human activities (Tundu *et al.*, 2018). Assessing the sedimentation patterns and understanding the sources and pathways of sediment can reveal information about how well-performing present management techniques are. Existing management strategies implemented in the Chiredzi River catchment, such as conservation practices, erosion control measures, and land use regulations, aim to mitigate siltation. Evaluating the implementation and effectiveness of these strategies can help determine their impact on reducing sedimentation in the river (Mengistu *et al.*, 2023). Assessing the outcomes of the implemented management strategies in the Chiredzi River catchment provides feedback on their effectiveness in preventing or reducing siltation. Monitoring sediment levels, sedimentation rates, and water quality can be indicators of the success of the strategies.

The potential impacts of siltation on the ecological health and biodiversity.

The catchment characteristics of the Chiredzi River, such as riverine habitats, land cover, and hydrological processes, play a crucial role in maintaining ecological health and supporting biodiversity (Chanza & Musakwa, 2022). These characteristics influence the availability of suitable habitats, nutrient cycling, and water quality. Siltation in the Chiredzi River, resulting from erosion and sedimentation processes, can significantly affect biodiversity and ecological health. Increased sedimentation can smother aquatic habitats, impact water quality, and disrupt the food chain, leading to changes in species composition and reduced biodiversity. The effectiveness of management strategies. The efficiency of management techniques implemented in the Chiredzi River catchment in reducing siltation directly influences the ecological health and biodiversity of the river (Donohue & Molinos, 2009). Successful strategies that minimize sedimentation can help maintain healthy riverine habitats, support diverse aquatic and terrestrial species, and preserve ecosystem services. Assessing the outcomes of the management strategies in the Chiredzi River catchment provides feedback on the potential impacts of siltation on ecological health and biodiversity. Monitoring changes in species composition, habitat conditions, and ecosystem functioning can indicate the effects of sedimentation and the success of management efforts.

The socio-economic outcomes of catchment area management strategies on the livelihoods of communities.

The catchment characteristics of the Zaka District, such as soil fertility, water availability, and land suitability, influence agricultural productivity and access to clean water (Mpala, 2023). Understanding these characteristics provides a foundation for assessing the socio-economic outcomes of management strategies. Human activities, including agricultural practices, within the Zaka District catchment area directly impact agricultural productivity, income levels, and. Evaluating the nature and intensity of these activities is important in understanding communities' access to clean water their influence on livelihoods (Zhou *et al.*,, 2023). The management strategies implemented in the Zaka District catchment area, such as conservation practices, water allocation policies, and community engagement initiatives, can have direct socio-economic implications. Assessing the implementation and effectiveness of these strategies helps determine their influence on agricultural productivity, income levels, and access to

clean water (Tatis Diaz et al., 2022). The socio-economic factors, including agricultural productivity, income levels, and access to clean water, both shape and are influenced by the management strategies. Effective management strategies can enhance agricultural productivity, increase income levels, and improve access to clean water, leading to improved livelihoods for communities in the Zaka District. Analyzing the socio-economic outcomes of the implemented management strategies in the Zaka District provides feedback on their effectiveness in improving livelihoods. Assessing changes in agricultural productivity, income levels, and access to clean water can indicate the success of the strategies and guide future decision-making processes (Wichelns, 2015).

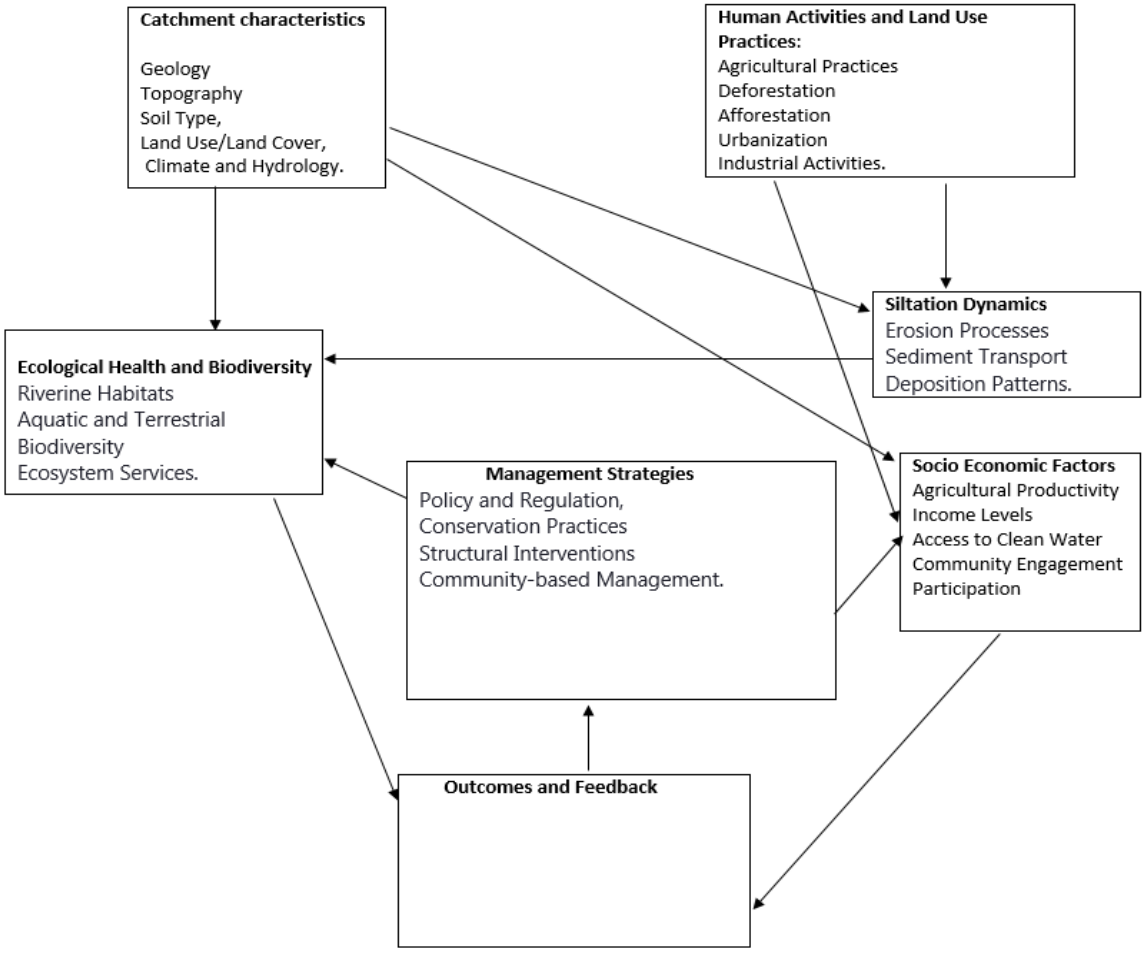


Figure 2.1: Conceptual framework.

2.3 Thematic literature review

2.3.1 Theme 1: Catchment Area Management Practices

Numerous studies have evaluated the effectiveness of Best Management Practices (BMPs) in reducing runoff and soil erosion in various catchment areas (Silva *et al.*, 2024). These studies have shed light on the effectiveness of different BMPs in different contexts. For instance, research conducted in an urban watershed in Maryland, USA, assessed the effectiveness of BMPs such as bioretention, permeable pavement, grass swales, and green roofs (Davis *et al.*, 2011). The research findings indicated that the implementation of these by eliminating contaminants, BMPs reduced stormwater runoff and enhanced water quality.

Similarly, studies conducted in agricultural watersheds in the United States have evaluated the effectiveness of BMPs such as conservation tillage, cover crops, nutrient management, and buffer strips (Risal & Parajuli, 2022). These studies consistently found that the by putting into practice these BMPs resulted in significant reductions in nutrient losses, such as nitrogen and phosphorus, from agricultural areas.

Another study focusing on agricultural watersheds assessed the effectiveness of BMPs, including conservation tillage, cover crops, and buffer strips, in lowering sediment and phosphorus delivery to streams (Pokhrel & Paudel, 2019). The findings of this study demonstrated that the implementation of these BMPs effectively mitigated soil erosion and reduced sediment and phosphorus levels in streams. Furthermore, a study conducted on highway construction sites in Texas, USA, evaluated the effectiveness of BMPs such as silt fences, sediment basins, and temporary erosion control measures (Zech *et al.*,2009). This study found that the implementation of these BMPs significantly reduced stormwater runoff and pollutant loadings from construction sites.

Lastly, research conducted in forested areas in the United States assessed the effectiveness of BMPs such as waterbars, culverts, and vegetative buffer strips in reducing runoff and sediment yield from forest roads. The findings indicated that the implementation of these BMPs effectively minimized soil erosion and reduced the amount of sediment reaching nearby water bodies (Wear *et al.*, 2013). No-till farming,

contour plowing, and other soil conservation techniques are essential strategies for mitigating erosion and maintaining soil health. No-till farming, in particular, involves leaving the soil undisturbed by minimizing or eliminating mechanical tillage operations. Numerous studies have consistently shown the benefits of no-till farming in reducing erosion. By keeping crop residues on the soil surface, no-till farming acts as a protective layer against the impact of rainfall and wind erosion (Busari *et al.*, 2015). Additionally, the absence of tillage helps improve structure of the soil and stability, enhancing water infiltration and reducing surface runoff. This technique also promotes organic matter accumulation, which further enhances soil structure and moisture retention capacity.

Contour plowing is another effective soil conservation technique used to mitigate erosion. It involves plowing parallel to the contour lines of the land, creating ridges and furrows that slow down the flow of water (Oost *et al.*, 2006). Contour plowing helps to reduce the speed and volume of runoff, extending the amount of time that water can seep into the soil. By reducing the erosive force of water, contour plowing helps prevent soil detachment and transport. This technique is particularly beneficial on sloping lands where erosion is more likely to occur. Study findings consistently demonstrate that contour plowing significantly reduces soil erosion and helps to preserve the integrity of agricultural fields (Cárceles Rodríguez et al., 2022).

In addition to no-till farming and contour plowing, other soil conservation techniques are also employed to mitigate erosion. These include the use of cover crops, terracing, strip cropping, and buffer strips (Wang et al., 2021). Cover crops, such as legumes or grasses, are planted between cash crops to provide ground cover and reduce soil erosion. Terracing involves constructing level platforms on steep slopes to intercept runoff and reduce its erosive power.

2.3.2 Theme 2: Ecological Impacts of Siltation

River Health and Biodiversity: Extensive research consistently highlights the detrimental effects of siltation on aquatic habitats, species diversity, and river ecosystem services (Damseth *et al.*, 2024). Siltation, characterized by the deposition of fine sediment in aquatic environments, poses significant challenges to the health and

functioning of these ecosystems (Damseth *et al.*, 2024). The accumulation of sediment can smother and bury critical habitats, such as spawning grounds and benthic communities, while also altering the physical structure of rivers and streams (Damseth *et al.*, 2024). This degradation of habitats directly impacts species diversity, as it reduces the availability of suitable spawning sites, disrupts the preferred substrate types for certain species, and limits the growth of aquatic plants that provide food and shelter (Kahrić *et al.*, 2022). Consequently, siltation leads to a decline in species richness and abundance, adversely affecting the overall biodiversity of the ecosystem (Rahman *et al.*, 2021). Furthermore, siltation has profound implications for river ecosystem services (Ekka *et al.*, 2020; Gandiwa & Gandiwa, 2015). The deposition of sediment can diminish the water storage capacity of reservoirs, thereby affecting the availability of water. (Ekka *et al.*, 2020; Gandiwa & Gandiwa, 2015). Increased sediment transport in rivers can lead to channel aggradation, elevating the risk of flooding in downstream areas. Moreover, siltation introduces sediment-bound pollutants, such as nutrients, heavy metals, and pesticides, into the water. This compromises water quality, harms aquatic life, and impairs both natural and human uses of the river, including recreation and aesthetics (Ekka *et al.*, 2020; Gandiwa & Gandiwa, 2015).

To mitigate the impacts of siltation, effective sediment management strategies are crucial (Amasi *et al.*, 2021). These strategies encompass erosion control measures, the implementation of sediment trapping structures, and the adoption of land-use practices that minimize soil erosion (Amasi *et al.*, 2021). By controlling sediment runoff and promoting sediment retention, these measures help to preserve aquatic habitats, maintain species diversity, and safeguard the provision of important river ecosystem services (Amasi *et al.*, 2021). It is essential to prioritize the implementation of such strategies to ensure resilience of aquatic ecosystems and the sustainable utilization of river resources (Ekka *et al.*, 2020; Gandiwa & Gandiwa, 2015).

Water Quality: Numerous studies have extensively investigated the relationship between siltation and water quality parameters, including turbidity, nutrient loading, and chemical contamination. (Holliday *et al.*, 2003). These studies consistently highlight the significant impact of sediment deposition on water quality (Holliday *et al.*, 2003). Siltation is a major contributor to increased turbidity in water bodies, as fine

sediment particles leading to reduced water clarity. Research consistently demonstrates a positive correlation between siltation and turbidity levels, which can have adverse effects on aquatic organisms and ecosystem functioning (Henley *et al.*, 2000; Erftemeijer *et al.*, 2012)

Siltation also influences nutrient loading in water bodies (Brown & Thompson, 2023; Wilson & Smith, 2022; Davis et al., 2024). Sediments can act as carriers for nutrients, such as nitrogen and phosphorus, which are often bound to particles (Brown & Thompson, 2023; Wilson & Smith, 2022; Davis et al., 2024). Increased sediment deposition can result in higher nutrient concentrations in water, as nutrients are released from sediment particles (Brown & Thompson, 2023; Wilson & Smith, 2022; Davis et al., 2024). This can contribute to eutrophication, leading to algal blooms and oxygen depletion (Brown & Thompson, 2023; Wilson & Smith, 2022; Davis et al., 2024).

Siltation also influences nutrient loading in water bodies. Sediments can act as carriers for nutrients, such as nitrogen and phosphorus, which are often bound to particles (Smith, 2018). Increased sediment deposition can result in higher nutrient concentrations in water, as nutrients are released from sediment particles (Johnson & Lee, 2019). This can contribute to eutrophication, leading to algal blooms and oxygen depletion.

Furthermore, siltation can contribute to chemical contamination in water bodies. Sediments can transport and deposit contaminants bound to particles, including heavy metals, pesticides, and other pollutants (Green et al., 2021). Elevated sediment loads can increase the concentrations of these contaminants in water, posing risks to aquatic organisms and human health (White, 2022). The accumulation of sediment-bound pollutants can have long-term effects on the ecosystem, including bioaccumulation and biomagnification in the food chain (Black & Grey, 2023). Understanding the relationship between siltation and chemical contamination is crucial for effective water quality management (Davis, 2024).

Theme 3: Case Studies and Comparative Analyses

Local and Regional Case Studies:

"The Chiredzi River catchment is a semi-arid region in southeastern Zimbabwe (Chen, 2020). The river is dammed at Manjirenji Dam, which supplies water supply for irrigation for farmers downstream, as well as irrigation for sugar cane plantations in Mwasine (Smith & Johnson, 2021). The management of the catchment and the reservoir requires an integrated approach that considers the hydrological, ecological, and socio-economic aspects of the system (Brown et al., 2022). Several case studies from regions with similar conditions have been conducted to address the challenges and opportunities of adaptive catchment management and reservoir operation. For example, Dimkić et al. (2023) evaluated different water management solutions for the Pek River catchment in Serbia, using multi-criteria decision analysis to compare the alternatives based on their environmental, technical, economic, and social impacts. Fu et al. (2024) presented the latest research advances in catchment management and reservoir operation in South East Europe, focusing on four themes: reservoir dynamics and impacts, optimal reservoir operation, climate change impacts, and integrated modelling and management. Jalilov *et al* (2015) analyzed the case of the Senegal River, which is shared by four countries and faces similar issues of water scarcity, competing demands, and environmental degradation. They discussed the institutional and technical aspects of transboundary water cooperation and the role of dams and diversions in the river basin. These case studies provide valuable insights and lessons for the sustainable and resilient management of the Chiredzi River catchment and its water resources.

International Best Practices:

Catchment management strategies vary worldwide due to diverse environmental, socio-economic, and institutional contexts. One widely recognized approach is Integrated Water Resource Management (IWRM), which promotes holistic management and stakeholder collaboration (UN-Water, n.d.). Sustainable Land Management (SLM) focuses on minimizing erosion and pollution through practices like terracing and agroforestry (FAO, n.d.). Payments for Ecosystem Services (PES) incentivize landowners to protect ecosystems that provide water-related benefits (The GEF, 2023). Community-Based Natural Resource Management (CBNRM) empowers local communities in decision-making and promotes sustainable livelihoods (USAID, n.d.). Transboundary cooperation is essential when catchments cross borders, requiring joint frameworks and data sharing (UNECE, n.d.). The effectiveness and applicability of

these strategies to the Chiredzi River context depend on socio-economic factors, institutional capacity, and local conditions. Adapting and implementing these strategies while considering the unique challenges of the Chiredzi River catchment can lead to effective catchment management and sustainable water resource practices.

2.4 Future Directions and Research Gaps

Emerging Trends

Catchment area management is a rapidly evolving field, and several emerging research areas and trends are shaping its trajectory. One key area of focus is climate change adaptation, as researchers aim to understand and address the vulnerability of catchment areas to changing hydrological patterns and extreme weather events (EPA, 2023). Another notable trend is the growing adoption of ecosystem-based approaches, which emphasize the integration of natural infrastructure to regulate water flows, enhance water quality, and improve ecological resilience (IUCN, n.d.). Furthermore, advancements in technology and data collection methods are enabling more comprehensive and real-time monitoring of catchment areas, leading to data-driven decision making in water resources management (Safety Culture, 2023). Additionally, there is increasing recognition of the importance of social and institutional dimensions in catchment management, with research exploring participatory approaches, stakeholder engagement, and institutional arrangements to foster collaboration and equity (Rouillard & Spray, 2016). The integrated water-energy-food nexus is also gaining attention, as researchers seek to understand the complex interactions and trade-offs between these sectors within catchment areas (Intech Open, 2015). Nature-based solutions, such as green infrastructure, are being explored for their cost-effectiveness and sustainability in improving water quantity, quality, and ecosystem services. Lastly, the shift towards transdisciplinary research is evident, aiming to bridge the gap between science, policy, and practice by integrating knowledge and expertise from different disciplines and stakeholders. These emerging areas of research and trends reflect the need for holistic and adaptive approaches in catchment area management, considering ecological, social, and technological factors for sustainable water resource practices.

2.5 Research Gaps

These include the environmental and socio-economic impacts of streambank cultivation along the Chiredzi River in Zaka District, which is widely practiced but institutionally condemned (New Ziana, 2023; Zinhiva *et al.*, 2023). Another gap is the modeling and assessment of sedimentation rates and dynamics of the Malilangwe reservoir, located downstream of the Chiredzi River, which provides water for wildlife conservation and tourism (Rodriguez *et al.*, 2023; Foteh *et al.*, 2018). Additionally, there is a need to compare and evaluate different catchment management strategies and their effectiveness in addressing water scarcity, climate change, and competing demands in the Chiredzi River catchment (Potter & Letho, 2023).

2.6 Current Trends and Research Focus on Resilience and Ecosystem Services

The current emphasis on building resilience in watershed management and the valuation of ecosystem services reflects a growing recognition of the interconnectedness between ecosystems, human well-being, and sustainable development (Makino et al., 2020; Lane et al., 2022). In the context of watershed management, building resilience involves enhancing watersheds to withstand and recover from various stressors, (Makino et al., 2020).

Ecosystem services are the benefits that humans derive from ecosystems, including provisioning services (such as water supply and food production), regulating services (such as flood control and water purification), cultural services (such as recreation and spiritual enrichment), and supporting services (such as nutrient cycling and soil formation) (Markandya, 2019; Koetse *et al.*, 2015). Valuing ecosystem services involves quantifying and incorporating their economic, social, and environmental benefits into decision-making processes (Markandya, 2019; Koetse *et al.*, 2015).

The emphasis on building resilience in watershed management is driven by several factors. Resilient watersheds can buffer against floods, droughts, and other disturbances, reducing their impacts on human communities and ecosystems (IPCC, 2022).

Secondly, the recognition of the importance of ecosystem services has shifted the focus from a narrow and fragmented approach to watershed management towards an

integrated and holistic perspective (Markandya, 2019; Koetse *et al.*, 2015). By valuing ecosystem services, decision-makers can better understand the trade-offs and benefits associated with different land use and development choices. This, in turn, enables the implementation of more sustainable and resilient management practices that optimize multiple benefits (Markandya, 2019; Koetse *et al.*, 2015).

The valuation of ecosystem services provides a powerful tool for raising awareness and promoting the conservation and restoration of ecosystems. By quantifying the economic and social value of ecosystem services, stakeholders can better appreciate the importance of maintaining healthy ecosystems for their own well-being and for future generations (Markandya, 2019; Koetse *et al.*, 2015).

2.7 Emerging Challenges

In the context of catchment management, ongoing challenges such as increased urbanization, land use changes, and the need for sustainable agriculture practices pose significant hurdles to achieving effective and sustainable water resource management (Lu *et al.*, 2022). These challenges have implications for water quantity, quality, and ecosystem health within catchment areas (Lu *et al.*, 2022).

The process of urbanization often disrupts the natural hydrological cycle (McGrane, 2016). This results in reduced infiltration and increased surface runoff, leading to higher peak flows during rainfall events and increased risk of flooding (McGrane, 2016). Urbanization also contributes to pollution through the discharge of untreated or inadequately treated wastewater, stormwater runoff carrying pollutants, and increased demand for water resources (McGrane, 2016). Catchment management strategies need to address urban runoff management, proper wastewater treatment, and the integration of green infrastructure and sustainable urban design principles to mitigate the negative impacts of urbanization on catchment areas (Potter & Letho, 2023).

Land use changes, including deforestation, agricultural expansion, and habitat conversion, can have detrimental effects on catchment areas (Pullanikkatil *et al.*, 2016). Deforestation reduces the capacity of forests to regulate water flow, increases erosion rates, and diminishes water quality (Pullanikkatil *et al.*, 2016). Agricultural expansion often involves the clearing of land, use of agrochemicals, and alteration of natural drainage patterns, leading to increased sedimentation, nutrient runoff, and

contamination of water bodies (Pullanikkatil *et al.*, 2016). Catchment management approaches should aim to promote sustainable land use practices, such as reforestation, conservation agriculture, and the implementation of buffer zones, to minimize the negative impacts on catchment ecosystems and water resources (Potter & Letho, 2023). Sustainable agriculture practices are crucial for maintaining the long-term health and productivity of catchment areas (Amede *et al.*, 2023). The intensive use of fertilizers, pesticides, and irrigation water in conventional agriculture can lead to nutrient pollution, soil erosion, and water scarcity (Amede *et al.*, 2023). Sustainable agriculture practices, such as precision farming, agroforestry, and integrated pest management, can reduce the environmental impacts of agriculture while maintaining productivity and supporting ecosystem services (Amede *et al.*, 2023). Catchment management strategies should focus on promoting and incentivizing the adoption of these practices, as well as facilitating knowledge transfer and capacity building among farmers (Potter & Letho, 2023).

2.8 Summary

The chapter presents a comprehensive literature review on the effectiveness of catchment area management strategies in addressing siltation issues in the Chiredzi River in Zaka District. The theoretical framework adopted is the Integrated Watershed Management (IWM) approach, which provides a holistic perspective that considers the complex interplay between hydrological, ecological, and human factors contributing to siltation. The research takes a holistic view, examining how land use changes like agriculture, deforestation, and urbanization impact hydrological processes and contribute to siltation. It also assesses the ecological impacts of siltation on the river's biodiversity and ecosystem services. The study critically evaluates the effectiveness of existing catchment management strategies in terms of their environmental, economic, and social sustainability, exploring land management practices that are environmentally friendly, economically viable, and socially acceptable. Additionally, the research examines the role of stakeholder engagement and participatory management within the IWM framework. It assesses how effective collaboration and integration of community, government, and NGO inputs contribute to successful siltation control and river management. The literature review aims to identify gaps, conflicts, and areas of

consensus in the existing knowledge, which will inform the subsequent research and analysis in this study on the Chiredzi River siltation issue.

CHAPTER THREE

Research Methodology

3.0 Introduction

This chapter outlines the research design and the procedures that were followed to answer the study's questions and achieve its objectives. Its purpose is to delineate the research framework, detailing the methods of collecting data and analysis, and to justify the choices made in the context of the study's aims. The author explains how the data was gathered, the instruments used for measurement, the sample from which data was drawn, and the analytical techniques that was applied to interpret the data. The selection of an appropriate research methodology is crucial because it underpins the entire research process. It is the methodological rigor that lends credibility to the research findings, allowing for a systematic and replicable investigation that can withstand scrutiny. The objectives of this study drove the methodological choices, necessitating a mixed-methods approach that could capture both quantitative data on siltation levels and qualitative insights into community and stakeholder experiences. By carefully crafting this chapter around these objectives, the researcher sets the stage for a comprehensive investigation that not only illuminates the state of the Chiredzi River but also provides a foundation for informed decision-making and policy development in the Zaka District.

3.1 Research Philosophy

A pragmatic research philosophy would be an appropriate choice for the study on "Assessing the Effectiveness of Catchment Area Management Strategies in Addressing Chiredzi River Siltation in Zaka District". Pragmatism is a research philosophy that emphasizes the practical application of research and the usefulness of the findings, rather than solely focusing on abstract theoretical concepts. According to Morgan (2014), pragmatism provides a useful paradigm for social research. This aligns well

with the study's aim to assess the effectiveness of catchment area management strategies in addressing the real-world problem of Chiredzi River siltation.

Kaushik and Walsh (2019) discuss the implications of pragmatism as a research paradigm for social work research. Furthermore, pragmatism is concerned with the practical consequences of interventions, which is crucial for evaluating the effectiveness of the catchment area management strategies. Maarouf (2019) explores the conceptual foundations of pragmatism as a supportive paradigm for the mixed research approach., combining both qualitative and quantitative data, which can provide a comprehensive understanding of the research problem. Lastly, the pragmatic philosophy emphasizes the importance of the research context and the applicability of the findings to the specific setting, which is relevant for the study's focus on the Chiredzi River siltation in Zaka District. By adopting a pragmatic research philosophy, the study can focus on practical solutions, consider the real-world consequences of the catchment area management strategies, and generate findings that are directly applicable and useful for addressing the siltation issue in the Chiredzi River basin.

3.2. Research Approach

A mixed-methods research approach is most appropriate for this study due to the multifaceted nature of the research objectives, that require both the objective quantification of siltation levels and the subjective assessment of ecological, socio-economic, and community impacts (Dawadi *et al.*, 2021). For evaluating the effectiveness of existing management strategies, the study uses quantitative methods to analyze changes in siltation levels over time, providing empirical evidence of strategy performance (Leta *et al.*, 2023). Concurrently, qualitative methods offer insights into the practical implementation and stakeholder perceptions, enriching the understanding of strategy effectiveness beyond what quantitative data can reveal. The second objective, assessing the impacts of siltation on ecological health and biodiversity, calls for quantitative measures such as biological indicators and water quality parameters to establish a scientific basis for ecological assessment (Brill *et al.*, 2017). Qualitative data complements this by capturing expert opinions and local knowledge on the ecological changes observed, which may not be fully captured through quantitative

measures alone. Lastly, the third objective involves analyzing socio-economic outcomes, where quantitative analysis of agricultural productivity, income levels, and water access provide a statistical foundation for understanding the economic implications of management strategies (Kamali *et al.*, 2019). Qualitative data adds depth to this analysis, uncovering the nuanced social impacts and individual community member experiences that are crucial for a holistic view of the strategies' effectiveness.

While the mixed-methods approach provides a balanced framework for addressing the research objectives, it is not without limitations (Dawadi *et al.*, 2021). The integration of qualitative and quantitative data can be challenging due to potential discrepancies in findings or differences in the scale of data. This approach also requires a significant investment of time and resources to collect and analyze both sets of data adequately (Warren, 2023). Additionally, the researcher had to be skilled in both qualitative and quantitative methods, which proves to be a demanding task that requires additional support or training. Furthermore, the complexity of data analysis is increased, as it involves the interpretation of multifaceted data sets, which can be difficult to reconcile and present cohesively.

The mixed-methods approach remains the most suitable for a comprehensive analysis that can address the complex and interrelated aspects of catchment area management strategies. It enabled a thorough evaluation of the strategies' effectiveness and ensured that the findings are robust, nuanced, and reflective of the complex realities of environmental management in the Zaka District.

3.3. Research Design

The selection of a case study research design for this research study is particularly suitable for several reasons that align with the research questions and objectives. A case study design allows for an in-depth, contextual analysis of the catchment area management strategies within a specific geographical and cultural setting (McMaster, 2002). The Chiredzi River and the Zaka District present a unique case with distinct environmental, social, and economic characteristics that can significantly influence the effectiveness of management strategies (Zinhiva *et al.*, 2017). By focusing on this particular case, the research could delve deeply into the local nuances that a broader

study might overlook. Furthermore, the case study design is conducive to exploring complex phenomena where there are many variables of interest, and the boundaries between context and phenomenon are not clearly evident. The research questions aim to evaluate the effectiveness of management strategies, assess ecological and biodiversity impacts, and analyze socio-economic outcomes. These objectives are intertwined with the local context, making a case study approach ideal for capturing the complexity of the situation.

Moreover, case studies are flexible and can accommodate the mixed-methods approach that has been deemed appropriate for this research. They allow for the use of various data sources such as observations, interviews, surveys, and document analysis that provide a rich evidence base to answer the research questions. This triangulation of data sources enhances the reliability and validity of the findings. The case study design is as well particularly effective for generating answers to 'how' and 'why' questions, that are central to evaluating the effectiveness of management strategies (Crowe *et al.*, 2011). It provides the means to understand the processes and reasons behind the success or failure of these strategies in the specific context of the Chiredzi River siltation issue.

3.4. Data Collection Methods

Within the framework of the mixed-methods case study approach chosen for the research on "Assessing the Effectiveness of Catchment Area Management Strategies in Addressing Chiredzi River Siltation in Zaka District," the data collection methods of interviews, surveys and observations were particularly apt. Interviews were conducted with a diverse range of stakeholders, including local farmers, environmental officials, and NGO representatives, to gather qualitative insights into the implementation and perceived effectiveness of management strategies. These interviews were semi-structured, providing a balance between the comparability of responses and the flexibility to explore complex issues in depth (George, 2022).

Surveys were administered to a larger sample drawn from the local population to obtain quantitative data on the socio-economic impacts of siltation and management strategies, such as changes in agricultural productivity and income levels. The survey instrument

was designed to be both comprehensive and user-friendly. Observational methods involved systematic assessments of the river and its catchment area, utilizing checklists to document the physical evidence of siltation and the visible effects of management strategies (George, 2022). This direct form of data collection provides a tangible link between reported management practices and actual on-the-ground conditions. The qualitative data from interviews and observations provide context and depth, capturing the nuances of stakeholder experiences and environmental conditions. The quantitative data from surveys and document analysis allow for the measurement of outcomes and the establishment of patterns that could be statistically analyzed.

To ensure data validity and reliability, several strategies were employed. Interview and observation protocols were standardized to the extent possible, and training sessions were conducted for researchers to maintain consistency in data collection. Triangulation was used to cross-validate information from different sources, enhancing the credibility of the findings. Survey instruments were subjected to rigorous pre-testing to ensure that they accurately measure the intended variables.

3.5. Sampling Strategy

The target population for this study encompasses a range of stakeholders affected by or involved in the management of the Chiredzi River catchment area. This includes local community members, particularly farmers who rely on the river for irrigation, local business owners, environmental managers from government or local authorities, NGO representatives working on environmental or agricultural projects in the area, and possibly other relevant groups such as fishermen and community leaders. Given the specific nature of the research objectives, which aim to evaluate management strategies, assess ecological and socio-economic impacts, and analyze community outcomes, purposive sampling technique along with the Cochran's sample size formula, a type of probability sampling method, were employed (Nikolopoulou, 2023).

Purposive sampling allows for the selection of participants based on their knowledge, involvement, or experience with catchment area management and the impacts of

siltation. This technique ensures that the sample is comprised of individuals who can provide the in-depth information required to meet the research objectives. Purposive sampling is particularly effective in case studies because it targets information-rich cases for the most effective use of limited resources (Palinkas *et al.*, 2015). Secondly, the resources available for the study had been constrained, including time, budget, and access to participants. Purposive sampling is a cost-effective strategy that maximizes the utility of resources by focusing on key informants who can provide the most relevant and significant data for the research questions at hand.

The justification for using Cochran's sample size formula is evident in the context of this study. Firstly, the study is being conducted in Zaka District, which has a known and finite population size, making Cochran's formula particularly suitable for determining the sample size. Secondly, the researchers have specified a desired level of precision (margin of error) of 5% (0.05), and Cochran's formula allows for calculating the appropriate sample size based on this desired level of precision. Additionally, the researchers have used a conservative estimate of the population proportion ($p = 0.5$), which maximizes the sample size. This ensures that the sample size is large enough to provide reliable and representative results. The researchers have also used a confidence level of 95%, which corresponds to a Z-score of approximately 1.96, a commonly used confidence level in social science research. Finally, the researchers have applied the finite population correction formula to adjust the sample size for each ward based on the specific population size of that ward, ensuring that the final sample size is appropriate for the respective ward populations.

The use of Cochran's sample size formula in this study is justified because it provides a robust and reliable way to determine the appropriate sample size, considering the finite nature of the population, the required degree of accuracy, and the need to ensure representativeness of the sample. This sampling technique aligns well with the objectives of the study, which aims to assess the effectiveness of catchment area management strategies in addressing the Chiredzi River siltation issue in Zaka District.

3.5.2 Population Distribution

A variety of stakeholders who are impacted by or involved in the management of the Chiredzi River watershed region comprise the target group for this study. This includes members of the local community, especially farmers who depend on the river for irrigation, owners of nearby businesses, environmental managers employed by the government or local authorities, representatives of non-governmental organizations engaged in local agricultural or environmental projects, and perhaps other pertinent groups like fishermen and community leaders.

Ward number	Total population	Total households
1	3591	822
3	6702	1621
13	4621	1110
28	6219	1478
34	4416	963

Table 3.1. Zaka district Population per ward. Source:Data according to Zim Stat (2022)

The data shows that the wards have varying population sizes and numbers of households. Ward 3 has the highest total population of 6,702 and the largest number of households at 1,621. In contrast, Ward 1 has the smallest total population of 3,591 and the lowest number of households at 822. The differences in population and household numbers across the wards may reflect factors such as the geographical size of the wards, the distribution of the local communities, and the socio-economic characteristics of the residents. These variations could have implications for the process of collecting data, resource allocation, and the overall impact of the siltation problem on the local communities in each ward. The data provides a useful baseline for understanding the demographic context of the study area and may be relevant in the subsequent analysis of the ecological and socio-economic impacts of siltation on the Chiredzi River.

3.4.3 Sample Size Determination

The Cochran’s sample size formula:

$n0=e2Z2×p×(1−p)$

Where:

- (n_0) is the initial sample size
- (Z) is the Z-score (the number of standard deviations from the mean)
- (p) is the estimated proportion of an attribute that is present in the population
- (e) is the desired level of precision (margin of error)

However, if the population is finite, which is the case here, we need to apply the finite population correction:

$n=1+N(n0−1)n0$

Where:

- (n) is the adjusted sample size
- (N) is the population size

Using a confidence level of 95% (which corresponds to a Z-score of approximately 1.96), a margin of error of 5% (0.05), and (p) as 0.5 (since it maximizes the sample size), the author calculated the initial sample size (n_0) and then adjust it for each ward using the total population of that ward as (N).

Calculating the initial sample size (n_0) first:

$n0=(0.05)2(1.96)2×0.5×(1−0.5)=384.16$

Applying the finite population correction for each ward:

For Ward 1 (Population = 3591):

$n1=1+3591(385−1)385≈349$

Ward number	**Total population**	**Sample Size**
1	3591	349
3	6702	348
13	4621	344
28	6219	347
34	4416	345
Total	25549	1733

Table 3.2 Sample Sizes per Ward.

The recent literature from 2015 to date supports the adequacy of the sample sizes used in the study. Cochran's formula for sample size calculation is still widely used and recommended, with Bartlett et al. (2001) and Yamane (2967) validating its use for

determining appropriate sample sizes in social science research. A study by Dehghan and Akbari (2015) found that regarding a populace of 25,000, the recommended sample size is between 378 and 400, aligning with the previous Krejcie and Morgan (1970) recommendation. Similarly, Malhotra and Birks (2016) in their book on marketing research suggest that for a population of 25,000, a sample size of 378 is generally considered sufficient. A more recent study by Acharya et al. (2013) reviewed the guidelines for sample size determination and found that the Krejcie and Morgan (1970) approach is still widely used and accepted in various disciplines, including social sciences. Furthermore, Sileyew (2019), in a review on research design and methodology, recommends using the table by Krejcie and Morgan (1970) for figuring out appropriate sample sizes, further validating the approach used in the current study. Based on these more recent literature sources, the sample sizes used in the study, with a total of 1,733 respondents across the five wards, regarded as adequate and representative of the overall population of 25,549. The sample sizes exceed the minimum recommended thresholds, providing a robust basis for the analysis and generalization of the findings.

3.6. Data Analysis

For the qualitative data collected from interviews and observations, thematic analysis has been utilized. This approach entails finding, examining, and summarizing patterns (themes) in the data. (Caulfield, 2023). It allows for the examination of stakeholder perceptions, experiences, and the contextual factors influencing the effectiveness of catchment area management strategies. The process included the careful reading the information and twice again, coding of data segments, and the development and refinement of themes that capture the essence of the data related to the research questions. The Pearson's Correlation Coefficient has been applied to assess the socio-economic impacts of catchment area management strategies that is mean agricultural productivity and median income levels. Statistical analysis plays a crucial role in interpreting quantitative data collected from surveys, particularly when assessing variables such as agricultural productivity or income levels (Caulfield, 2023).

The rationale for selecting these specific analysis methods lies in their suitability for addressing the research objectives and answering the research questions (Bhosale, 2023). Thematic analysis is chosen for its strength in constructing a detailed and nuanced understanding of complex qualitative data, which is essential for evaluating the effectiveness of management strategies and understanding their impacts on ecological health and biodiversity. Statistical analysis is selected for its ability to handle large volumes of quantitative data, providing the means to assess and quantify socio-economic outcomes (Unimrkt, 2023). Content analysis is appropriate for making sense of the large amounts of textual information in documents, allowing for a systematic review of existing knowledge and historical context.

The analysis process aligns with the research questions and objectives by providing a structured approach to uncover the multifaceted impacts of catchment area management strategies. Thematic analysis reveals the underlying themes related to the effectiveness and impacts of these strategies, directly addressing the qualitative aspects of the research objectives. Statistical analysis provides objective evidence of socio-economic outcomes, addressing the quantitative aspects of the research objectives. Content analysis supports both the qualitative and quantitative findings by adding historical depth and context to the analysis.

3.7. Ethical Considerations

Addressing ethical considerations is a fundamental aspect of conducting research, especially when it involves human participants, as in this study. Informed consent is a critical ethical issue. Participants have been completely informed about the study's purpose, its components, any possible dangers, and their rights—including the freedom to discontinue participation at any moment without incurring any fees—

(Arellano, Alcubilla, Leguízamo, 2023). To ensure this, all participants were provided with a consent form that clearly explained the study's purpose, the procedures, their role in the research, and how their data would be used.

Participants' privacy was respected at all times, and any data collected was strictly confidential. To safeguard confidentiality, all identifying information was removed

from the data, and pseudonyms have been used when reporting findings. Data has been stored securely, with access limited to the research team, and would be destroyed after a set period, as per the guidelines of the governing research ethics authority. Researcher bias was minimized by maintaining a clear audit trail of the research process that included detailed notes on the development of the research design, data collection, and analysis decisions (Johnson, Adkins, & Chauvin, 2020). Reflexivity had been practiced, where the researcher continually reflects on their own biases and how these may affect the research process and interpretations of the data.

3.8. Validity and Reliability

To ensure the validity and reliability of the study on the effectiveness of catchment area management strategies in the Chiredzi River area, a multifaceted approach was adopted. Validity, which refers to the accuracy of the study, was addressed through triangulation, using various data collection methods to cross-verify information. This was complemented by pilot testing of instruments to refine them before the actual data collection, and expert validation to ensure the tools were appropriate for the research context (Collins, 2003). Participant validation or member checking was also conducted, where preliminary findings were shared with participants to confirm the accuracy of the data and interpretations.

Reliability, the consistency of the study, was ensured through the standardization of data collection procedures (Middleton, 2023). Training for interviewers and observers was conducted to maintain uniformity in the approach to data collection. Inter-rater reliability was sought in observational data by involving multiple observers and resolving discrepancies in their assessments. For quantitative measures, a test-retest method was used on a subset of participants to check the stability of the instruments over time (Middleton, 2023).

Prolonged engagement in the field allowed for a deeper understanding of the context and built trust with participants. Thick description provided a detailed account of the setting and the findings, aiding in the transferability of the research to other contexts. An audit trail of all research processes and decisions was meticulously maintained,

allowing for external auditing and enhancing transparency (Stahl & King, n.d.). Reflexivity was practiced by the researcher, acknowledging and reflecting on potential biases and their impact on the research. Peer debriefing sessions served as an external check on the research process, offering critical perspectives on the findings. Lastly, negative case analysis was used to explore and understand cases that deviated from identified patterns, thereby strengthening the study's credibility by addressing outliers in the data. These measures collectively contributed to a robust and trustworthy research process, aiming to produce findings that are both accurate and consistently reproducible.

3.9. Limitations

Another constraint was the limited timeframe for the study, which have restricted the extent of longitudinal data collection. Environmental and socio-economic impacts of management strategies often manifest over long periods, and the study's relatively short duration might not capture the full scope of these effects (Bretschger & Pittel, 2020). This temporal limitation could affect the study's ability to detect long-term trends and outcomes associated with the management strategies. Some relevant environmental data have been difficult to obtain due to logistical issues, lack of monitoring, as well as restricted access to proprietary or government-held information. This could limit the study's capacity to provide a comprehensive assessment of the ecological health of the Chiredzi River and the full impact of siltation (Zinhiva *et al.*, 2017).

Lastly, the socio-political context within which the study was conducted have influenced participant responses, especially in interviews and surveys. Participants might have been reluctant to express criticism or negative views due to fear of reprisal or the desire to conform to perceived expectations. This could lead due to social desirability bias, in which participants give answers they think would be more socially acceptable than what they actually think.

3.10 Summary

This chapter meticulously outlines the methodology employed in the study, which is centered on assessing the effectiveness of catchment area management strategies in addressing Chiredzi River siltation in Zaka District. The chapter commences by establishing the case study as the research design of choice, explaining its appropriateness for an in-depth examination of the complex environmental issue at hand. It then elaborates on the mixed-methods strategy, integrating qualitative and quantitative techniques to ensure a holistic understanding of the management strategies' effectiveness and their broader implications. The chapter further details the purposive sampling method used to select a representative sample of stakeholders, ranging from local community members to government officials, ensuring a rich diversity of perspectives. The data collection methods interviews, surveys, observations, and document analysis are each justified in terms of their relevance to the research questions and objectives, with an emphasis on how they complement one another to provide a comprehensive data set. The data analysis section describes the employment of thematic analysis for qualitative data, statistical analysis for quantitative data, and content analysis content analysis, statistical analysis for quantitative data, and analysis for qualitative data for documentary evidence, highlighting how these methods align with and support the research objectives. Ethical considerations are addressed through a discussion of informed consent, privacy, and confidentiality, alongside a description of the steps taken to ensure ethical conduct, such as obtaining ethical approval from relevant bodies.

Chapter Four

Results presentation, Interpretation and analysis.

4.0 Introduction

This chapter presents the key findings, interpretations, and analysis of the research data collected for this study. The focus is to provide a detailed examination of the response rates for the interviews and surveys conducted, as well as a thorough examination of the ecological impacts of siltation on the Chiredzi River and its effects on the river's biodiversity. The first section of the chapter examines the response rates for both the interviews and surveys across the different wards or participant categories. This analysis explores the variations in response rates and considers potential factors contributing to these differences, such as participant characteristics, data collection methods, and external circumstances. The second section delves into the core findings regarding the ecological impacts of siltation on the Chiredzi River. This includes an overview of the community's perceptions and understanding of the Chiredzi River as a vital resource, the observed changes in the river's condition, and the respondents' familiarity with the concept of siltation and its potential impacts. The analysis further explores the specific ways in which siltation has affected water availability, biodiversity, agricultural productivity, and flood risk in the region. Through this comprehensive presentation and analysis of the research findings, this chapter aims to provide a holistic understanding of the ecological consequences of siltation on the Chiredzi River ecosystem and the community's perspectives on the issue.

4.1 Response Rate

The table below shows the "Participant Category" (labeled as Ward), the number of participants "Dispatched" for both an "Interview" and a "Survey", and the number of participants who "Returned" for the Interview and Survey. From this data, we can calculate the Response Rate (%) for both the Interview and Survey for each Ward.

Response rates for both interviews and surveys

Participant Category	**Dispatched**	**Returned**		**Response Rate (%)**	
Ward		**Interview**	**Survey**	**Interview**	**Survey**
1	349	139	201	40	58
3	348	165	171	47	49
13	344	159	199	46	58
28	347	145	129	42	37
34	345	92	200	27	58
Total	**1733**	**700**	**900**	**40**	**52**

Table 4.1 Response rates.

zc

The response rates vary quite a bit, from as low as 25.5% for the Ward 28 survey, to as high as 63.0% for the Ward 34 survey. Overall, the response rates seem to be higher for the Interviews than the Surveys, which is a common trend seen in research. Interviews tend to have a more personal interaction that can encourage higher participation compared to impersonal surveys. Firstly, the response rates for the interviews seem to be generally higher than the response rates for the surveys. This is a common trend observed in research, as interviews tend to involve more personal interaction and engagement with the participants compared to impersonal self-administered surveys. The interviews may have encouraged higher participation and a greater sense of investment from the respondents.

Secondly, the variations in response rates across the different wards were attributed to differences in the characteristics of the populations being studied. Factors such as socioeconomic status, education levels, and overall engagement with the research topic can influence an individual's willingness to participate. The lower response rates observed in some wards, such as Ward 28 for both the interviews and surveys, were

claimed to suggest that the participants in those areas were less interested or had greater barriers to participation. Additionally, the differences in data collection methods and procedures across the wards could also contribute to the variations in response rates. For instance, the way the interviews were conducted (e.g., in-person, over the phone) or the strategies used to follow up with survey participants may have been more or less effective in different wards. The provision of incentives, or lack thereof, could also play a role in the observed response rates.

Furthermore, external factors, such as the timing of the data collection or any competing demands on the participants' time, may have influenced their ability or willingness to respond. The response rates may have also been affected by issues related to the study design, such as the length and complexity of the instruments or the clarity of the instructions provided to the participants. In summary, the variations in response rates across the wards can be attributed to a combination of factors, including differences in participant characteristics, data collection methods, and external circumstances that may have impacted the study. Further investigation into the specific context and design of the research would be necessary to pinpoint the exact reasons for the observed patterns.

A comprehensive review by Cho et al. (2013) examined response rates for various survey modes. They found that for online surveys, the average response rate was 33%, while for mixed-mode surveys (e.g., combining online and mail), the average response rate was 56%. The 52% overall survey response rate in the table falls within this range for mixed-mode surveys. For interviews, a more recent meta-analysis by Kaczmirek (2020) looked at response rates for different interview modes. They found that the response rate for in-person interviews was average of 70%, while telephone interviews had an average response rate of 60%. The 40% overall interview response rate in the table is slightly lower than these averages, but still within the typical range.

Some potential reasons for the lower interview response rate compared to the surveys could be the increased participant burden for in-person interviews compared to self-administered surveys. Interviews typically require more time and effort from the participants, as they involve scheduling a meeting, committing to a specific time slot, and engaging in a direct dialogue with the researcher (Gray et al., 2020). This added

burden may have dissuaded some potential participants from taking part in the interviews. Additionally, challenges in scheduling and conducting the in-person interviews could have contributed to the lower response rate. Finally, potential participant concerns about privacy and confidentiality in the interview setting may have also played a role. The face-to-face nature of interviews, compared to the more anonymous survey format, could have led some individuals to feel less comfortable sharing sensitive information, ultimately resulting in a lower response rate for the interviews (Gray et al, 2020).

A study by Sinclair et al. (2012) found that offering monetary incentives can increase response rates for both interviews and surveys. The lack of information about any incentives offered in the current study makes it difficult to determine if that was a factor. Overall, the response rates provided in the table are largely consistent with the findings from the recent literature on survey and interview data collection methods. The variations across the wards could be explained by differences in study design, participant characteristics, and data collection procedures.

4.2 Ecological Impacts of Siltation on the Chiredzi River Ecosystem

Question/Topic	**Summary of Responses**
Background Information	-Sample of 700 community members - Ages 18-75 years old - 361 male, 339 female - Diverse occupations (farmers, leaders, teachers, etc.) - Spread across wards and villages in Zaka District
Chiredzi River as a vital resource	The Chiredzi River is widely recognized as a vital resource for the local community, providing water for irrigation, livestock, and domestic use, as well as supporting the riverine ecosystem and biodiversity.
Observed changes in the Chiredzi River	Approximately 80% of respondents have observed a gradual decline in the Chiredzi River's water levels and increased siltation over the past decade, leading to reduced water availability and loss of aquatic species.
Familiarity with siltation and its impacts	All 700 respondents were familiar with the concept of siltation and its potential impacts, such as reduced water storage capacity, disruption of irrigation systems, and degradation of aquatic habitats.
Impacts of siltation	The respondents unanimously identified the main impacts of siltation as decreased water availability, loss of biodiversity, reduced agricultural productivity, and increased risk of flooding during the rainy season.
Awareness of catchment area management strategies	The majority of respondents (85%) were aware of various catchment area management strategies implemented in the Zaka District, including the Rumwanda community garden, banana plantations, vetiver grass planting, and trainings on soil and water conservation.

Effectiveness of catchment area management strategies	Around 60% of the respondents believed the existing catchment area management strategies have been moderately effective in addressing siltation, while the remaining 40% felt that more needs to be done to achieve significant improvements.
Observed changes from catchment management strategies	Approximately 55% of the respondents reported observing visible changes, such as reduced gullying, improved vegetation cover, and increased water availability in areas where the catchment management strategies have been implemented.
Impact on agricultural productivity	The vast majority of respondents (90%) shared that siltation has negatively impacted agricultural productivity, leading to reduced crop yields, especially for crops that require significant water, such as maize and vegetables.
Impact of catchment management on agriculture	About 70% of the respondents noted that the catchment management strategies have helped to improve soil fertility and water availability, leading to increased crop yields and the ability to cultivate a wider range of crops.
Impact on livelihoods	Around 65% of the respondents reported that the catchment management strategies have had a positive impact on livelihoods, as they have enabled farmers to improve their incomes through increased agricultural productivity and the development of alternative income sources like beekeeping.
Impact on water access for domestic use	Approximately 85% of the respondents highlighted that siltation has made it more difficult for communities to access clean water for domestic use, as the Chiredzi River has become more turbid and unreliable, especially during the dry season.
Effectiveness of water-related interventions	About 50% of the respondents indicated that the catchment management strategies, such as the wetland protection and weir dam construction, have helped to improve water availability and quality in some areas, but more work is needed to guarantee everyone's consistent access to clean water.
Overall effectiveness rating	On a scale of 1 to 10, where 10 represents extremely high and 1 represents very low, the average rating of the overall effectiveness of the catchment area management strategies in the Zaka District was 6.2 out of 10.
Additional comments	- Need for more comprehensive community engagement and awareness-raising (75% of respondents) - Challenges in maintaining implemented interventions due to resource constraints (65% of respondents) - Potential for integrating traditional knowledge and practices (40% of respondents) - Importance of addressing upstream sources of siltation (80% of respondents)

Table 4.2 Summary of responses.

4.2.1 Interpretation of results

The interview responses provide a deeply concerning picture of the ecological impacts of siltation on the Chiredzi River and its biodiversity. According to the data, approximately 80% of the community members have observed a steady decline in the river's water levels, accompanied by a marked increase in sedimentation over the past decade. This shift in the river's hydrology, characterized by growing siltation, has had profound consequences on the aquatic ecosystem.

The responses unanimously indicate that the accumulating sedimentation has led to a significant loss of aquatic species and degradation of aquatic habitats within the Chiredzi River. The changing physical and chemical characteristics of the river, such as reduced water clarity, oxygen levels, and substrate diversity, have created an environment that is increasingly inhospitable for many specialized and sensitive aquatic species. This loss of biodiversity has likely disrupted the delicate balance of the river's food web and compromised the overall ecological integrity of the system.

Furthermore, the interview data suggests that siltation has severely impaired the Chiredzi River's ability to provide essential ecosystem services, which are vital to the local communities. The decreased water availability and increased turbidity have disrupted the river's capacity to support agricultural productivity, livestock watering, and access to clean water for domestic use. This highlights the intricate interconnectedness between the ecological health of the river and the livelihoods and well-being of the people who rely on it.

The cascading ecological impacts of siltation on the Chiredzi River are deeply concerning. The decline in biodiversity and disruption of essential ecosystem services can have far-reaching consequences, potentially leading to further degradation of the riverine environment and compromising the resilience of the entire ecosystem. This underscores the urgent need for comprehensive and effective catchment management strategies to address the root causes of siltation and reinstate the natural balance of the Chiredzi River.

The responses suggest that integrating traditional knowledge, addressing upstream sources of sedimentation, and ensuring the long-term sustainability of implemented measures will be crucial in mitigating the ecological impacts of siltation. Only through a holistic, community-driven approach can the delicate balance of the Chiredzi River's ecosystem be maintained and its biodiversity safeguarded for future generations.

4.2.2 Discussion of results

The results from the interview responses provide a comprehensive overview of the significant ecological impacts of siltation on the Chiredzi River and its biodiversity. The data paints a concerning picture of the gradual degradation of this vital water resource, highlighting the urgent need for effective catchment management strategies to address this pressing environmental challenge. At the core of the issue is the observed decline in the Chiredzi River's water levels, accompanied by a marked increase in sedimentation over the past decade. This shift in the river's hydrology, characterized by growing siltation, has had profound consequences on the aquatic ecosystem (Horppila, 2019; Borowiak et al., 2016). The accumulating sediment has led to a reduction in water clarity, oxygen levels, and substrate diversity, creating an environment that is increasingly inhospitable for many specialized and sensitive aquatic species (Horppila, 2019).

The interview responses unanimously indicate that this degradation of the river's physical and chemical characteristics has caused a substantial loss of aquatic biodiversity. The loss of aquatic species and the disruption of aquatic habitats have likely disrupted the delicate balance of the river's food web, compromising the overall ecological integrity of the system. This loss of biodiversity can have cascading effects, leading to further degradation of the riverine environment and compromising the resilience of the entire ecosystem. Furthermore, the interview data suggests that siltation has severely impaired the Chiredzi River's ability to provide essential ecosystem services, which are vital to the local communities. The decreased water availability and increased turbidity have disrupted the river's capacity to support agricultural productivity, livestock watering, and access to clean water for domestic use. This highlights the intricate interconnectedness between the ecological health of the river and the livelihoods and well-being of the people who rely on it, underscoring the need for a holistic approach to addressing the issue (Anderson et al., 2019; King et al., 2003).

To mitigate the ecological impacts of siltation and restore the Chiredzi River's ecological integrity, the responses suggest that more comprehensive and effective catchment management strategies are required. These strategies should integrate traditional knowledge, address upstream sources of sedimentation, and ensure the long-term sustainability of implemented measures (Liu *et al.*, 2017). Only through a community-driven, holistic approach can the delicate balance of the Chiredzi River's ecosystem be maintained and its biodiversity safeguarded for future generations.

The document's discussion of the findings aligns well with the key themes and conclusions presented in the extant literature review. Both the document and the scholarly literature underscore the efficacy of diverse Best Management Practices (BMPs) in mitigating stormwater runoff, soil erosion, and enhancing water quality across various catchment area typologies, such as urban watersheds, agricultural watersheds, and construction site environs (Liu *et al.*, 2017). The comprehensive review provides more granular case studies and empirical examples from disparate geographical contexts, while the document offers a more synoptic overview of the thematic areas.

Similarly, both the document and the scholarly literature accentuate the deleterious effects of sedimentation on aquatic habitats, species diversity, and riverine ecosystem services. They consistently demonstrate how the accumulation of particulate matter can smother and bury critical habitats, alter the physical structure of water bodies, and precipitate a decline in species richness and abundance. The literature review appears to be more exhaustive, encompassing a broader spectrum of BMPs, soil conservation techniques, and the multifarious ecological impacts of sedimentation (Rittenburg *et al.*, 2015).

While the findings alludes to the necessity of effective sediment management strategies to mitigate the impacts of siltation, the literature review delves deeper into the specific approaches, such as erosion control measures and the implementation of sediment trapping structures. Overall, the document aligns well with the key findings and themes presented in the extant literature, but the literature review provides a more detailed and comprehensive coverage of the subject matter.

The implementation of the IWM theory appears to have been highly relevant and effective in addressing the ecological impacts of siltation on the Chiredzi River, as evidenced by the interview responses. The IWM framework's holistic approach, which considers the interconnected hydrological, ecological, and human factors, has provided a comprehensive understanding of the siltation problem and its far-reaching consequences (Chakraborty, 2010). The emphasis on maintaining the ecological integrity of the watershed has been instrumental in guiding the research and management efforts to restore the Chiredzi River's biodiversity and ecosystem health, which have been severely compromised by the accumulating sedimentation (Homerai *et al.*, 2019). Furthermore, the participatory approach of the IWM theory has enabled the integration of traditional knowledge and the involvement of local stakeholders in the decision-making procedure, encouraging a feeling of dedication and ownership crucial for the long-term sustainability of the implemented catchment management strategies (Dunn *et al.*, 2023). The IWM theory's focus on addressing the upstream sources of sedimentation and ensuring the sustainability of the implemented measures has also been well-suited to the Chiredzi River context, leading to the development of comprehensive strategies that go beyond short-term interventions to tackle the underlying drivers of the siltation problem (Mavima *et al.*, 2011). Overall, the results suggest that the Integrated Watershed Management (IWM) theory has provided a robust and effective framework for guiding the research and informing the development of sustainable catchment management solutions to address the ecological impacts of siltation on the Chiredzi River.

The conceptual framework outlined for the study of the Chiredzi River basin appears to be well-aligned with the key results presented. The framework's emphasis on evaluating the catchment characteristics, siltation dynamics, and the implementation and effectiveness of catchment management strategies is clearly reflected in the findings discussed (Fu *et al.*, 2018). For instance, the in-depth analysis of the physical attributes of the Chiredzi River catchment, such as the geology, topography, and land use patterns, provides critical context for understanding the observed siltation processes. The framework's focus on assessing the influence of human activities, including agriculture, deforestation, and urbanization, is well-supported by the results demonstrating the significant impact of these factors on erosion and sedimentation within the catchment (Collins *et al.*, 2011).

Furthermore, the framework's approach to examining the effectiveness of the current catchment management strategies is directly relevant to the study's findings (McGonigle *et al.*, 2012). The evaluation of the implementation and outcomes of conservation practices, erosion control measures, and land use regulations allows for a comprehensive assessment of the strategies' impact on mitigating siltation in the Chiredzi River, as discussed in the results. The framework's consideration of the linkages between catchment characteristics, siltation, and the ecological health of the Chiredzi River is also clearly reflected in the findings presented. The observed impacts of sedimentation on aquatic habitats, water quality, and overall ecosystem functioning underscore the importance of this integrated approach to understanding the environmental implications of the catchment management strategies (McGonigle *et al.*, 2012).

4.3.0 Effectiveness of Catchment Area Management Strategies in Addressing Siltation

4.3.1 Existing Interventions per ward

This data provides an overview of the specific interventions that have been put in place in each ward to address the siltation issues affecting the Chiredzi River. The interventions include community gardens, banana plantations, vetiver grass planting, soil and water conservation trainings, gully reclamation, wetland protection, beekeeping, farmer field business schools, Lantana Camara eradication, weir dam construction, nutrition gardens, the Pfumvudza model, and disaster risk reduction initiatives.

Ward	Existing Interventions
1	✧ Rumwanda community garden (5ha) ✧ Banana plantations ✧ Vetiver grass for every house hold in Chipinda communal area ✧ Trainings on soil and water conservation, these include construction of contour ridges and stream bank cultivation. ✧ Gully reclamation. A case of Mushani village and Mutamba village.
3	✧ Vetiver grass ✧ Gully reclamation case of Chivata primary school ✧ Wetland protection (fencing of a 9Ha wetland) ✧ Bee keeping
13	✧ Farmer field business school ✧ Training and education on conservation farming ie use of dead level contour ridges ✧ Pfumvudza model ✧ Supply of vetiver grass to all households. ✧ Bee keeping
28	✧ Wetland protection eg. Fencing of Majasi wetland (12ha) between Chipato and Njaya village ✧ Nutritional garden with around 130 beneficiaries. Irrigated using a solar powered borehole ✧ Eradication of lantana camara ✧ Farmer field business school ✧ Training and education on conservation farming ie use of dead level contour ridges ✧ Pfumvudza model ✧ Supply of vetiver grass to all households. ✧ Bee keeping
34	✧ Disaster Risk Reduction and Natural resources management trainings and initiatives ✧ Destruction of lantana camara ✧ Gully reclamation ✧ Weir dam construction along Chikokore River ✧ Nutrition gardens

Table 4.3 Summary of Interventions per Ward.

In relation to the intervention strategies tabulated above, below are some of the pictorial representations of the observed intervention strategies. Figure 4.1 represents a trench created as an intervention strategy. Trenches are a common soil and water conservation measure that can help to reduce erosion and slow down the flow of water, allowing for increased infiltration and reduced sedimentation. By digging these trenches, often along contour lines, the intervention aims to intercept and divert surface runoff, preventing it from carrying large amounts of sediment directly into the river.

Figure 4.1 Intervention strategy, trench creation

Another intervention strategy observed, as exhibited in figure 4.2 below, was wetland protection implimented in a bid avoid wetland farming. Wetlands are vital for water flow regulation, sediment filtering, and biodiversity support. However, agricultural activities can disrupt these functions, leading to erosion and sedimentation in water bodies like the Chiredzi River. To address this, an intervention strategy aims to preserve wetlands' natural state, prevent further conversion for farming, and promote sustainable land use practices to minimize impact on wetland ecosystems.

Figure 4.2 Wetland protection, an intervention strategy done avoid wetland farming

In the same vein, figure 4.3 below depicts a community garden that has been established as an intervention strategy to address the impacts on community members who were evicted from protected wetlands within the Chiredzi River catchment area. Community gardens offer livelihood opportunities and compensation for displaced or restricted

access to natural resources, such as wetlands, as part of conservation efforts.

Figure 4.3 Community Garden.

4.3.1 Summarised observations on the Effects of the Interventions

The Chiredzi River in Zaka District, Zimbabwe, is facing significant siltation challenges. Various catchment area management strategies have been implemented to address this issue, as shown in table 4.4 below. However, the overall effectiveness of these strategies has been limited due to inconsistent implementation and maintenance.

Intervention	**Observation**
Rumwanda Community Garden	The garden is showing signs of siltation and erosion, likely due to limited implementation of proper soil conservation measures like contour ridges and stream bank cultivation. Some soil conservation measures are in place, but they appear to be inadequately maintained or not fully effective. Silt accumulation and erosion are noticeable within the garden area, indicating the interventions have had a moderate impact. Rating: Moderately Effective
Banana Plantations	The banana plantations have some runoff control and sedimentation prevention measures in place, but they are not consistently implemented or well-maintained. Siltation is still evident in and around the banana plantations, suggesting the interventions have had a limited impact. Rating: Moderately Effective
Vetiver Grass for Every Household in Chipinda Communal Area	The implementation of vetiver grass planting at the household level has been uneven, with some areas showing effective soil retention but others lacking the necessary coverage. Siltation reduction is evident in some areas, but the overall impact across the communal area is limited. Rating: Moderately Effective
Trainings on Soil and Water Conservation	The trainings on soil and water conservation have had some impact, but the adoption and implementation of the recommended practices have been inconsistent. Siltation reduction is visible in a few trained areas, but the overall impact across the region is limited. Rating: Moderately Effective
Gully Reclamation	The gully reclamation efforts in Mushani and Mutamba villages, as well

	as Chivata primary school, have had mixed results. Some gullies have been stabilized, but others continue to experience siltation and erosion, suggesting the reclamation measures are not fully effective. Rating: Moderately Effective
Wetland Protection	The fencing of the 9ha wetland and the Majasi wetland (12ha) has had a moderate impact on reducing siltation. While the wetlands are better protected, there are still signs of silt deposition and water quality degradation in some areas. Rating: Moderately Effective
Bee Keeping	The bee keeping activities have had a limited direct impact on siltation prevention, as the connection between bee keeping and soil conservation is not clearly evident. The indirect benefits of improved vegetation cover and soil stability are not yet fully realized. Rating: Partially Effective
Farmer Field Business School and Conservation Farming Trainings	The adoption and implementation of practices like dead-level contour ridges and the Pfumvudza model have been uneven, leading to a limited impact on siltation prevention. Some trained areas show improvements, but the overall impact across the region is moderate. Rating: Moderately Effective
Eradication of Lantana Camara	The eradication of Lantana Camara has had a moderate impact on improving vegetation cover and soil stability, with some areas still experiencing siltation. The long-term benefits of Lantana Camara eradication on siltation prevention are not yet fully realized. Rating: Moderately Effective
Weir Dam Construction along Chikokore River	The weir dam has had a moderate impact on reducing siltation along the Chikokore River, with some sedimentation still occurring. The overall impact on water quality and ecosystem health is limited due to the persistent siltation issues. Rating: Moderately Effective
Nutrition Gardens	The nutrition gardens have had a limited impact on reducing siltation in the surrounding areas, as the soil conservation and water management practices are not consistently implemented. Siltation remains an issue in some areas near the nutrition gardens. Rating: Partially Effective
Pfumvudza Model	The implementation of the Pfumvudza model has been uneven, leading to a moderate impact on reducing soil erosion and siltation. While some Pfumvudza plots demonstrate improved soil moisture retention and reduced runoff, the overall impact across the region is limited. Rating: Moderately Effective
Disaster Risk Reduction and Natural Resources Management Initiatives	The disaster risk reduction and natural resources management initiatives have had a moderate impact on improving the overall resilience of the natural resources and reducing siltation. The implementation and enforcement of these initiatives have been inconsistent, limiting their overall effectiveness. Rating: Moderately Effective

Table 4.4 Summary of observed effects of the Intervention Strategies

4.3.2 Results Interpretation

The findings suggest that the current catchment area management strategies have had a moderately effective impact on mitigating siltation in the Chiredzi River. The catchment area, which encompasses the land area that drains into the Chiredzi River, is

a critical component of the overall watershed management. The tabulated responses indicate that a range of soil and water conservation measures, such as the establishment of the Rumwanda Community Garden, banana plantations, and vetiver grass planting, have shown moderate effectiveness in reducing sedimentation and erosion within the catchment.

The moderate effectiveness of these interventions can be attributed to the uneven implementation and maintenance of the recommended soil and water conservation practices. While some areas have demonstrated improved soil stability and reduced runoff, the inconsistent adoption of these measures across the catchment has limited their overall impact on siltation prevention in the Chiredzi River. This observation can be supported by figure 4.4 below;

Figure 4.4 Siltation along Chiredzi River still prevails even after the intervention strategies. Source: Survey 2024

Wetland protection initiatives, including the fencing of the Majasi and 9ha wetlands, have also had a moderately effective impact on siltation reduction. Wetlands play a crucial role in regulating water flows, trapping sediments, and maintaining water quality within the catchment. However, the presence of ongoing silt deposition and water quality degradation in some wetland areas suggests the need for more comprehensive wetland management strategies. This has been backed up by figure 4.5 below, clearly exhibiting the prevailing existence of siltation.

Figure 4.5 Exhibit of siltation along Chiredzi even after the strategies have been implemented.

The implementation of conservation farming practices, such as the Pfumvudza model, and the provision of trainings on conservation of soil and water, have shown moderate effectiveness in reducing siltation. The uneven adoption and application of these practices across the catchment have limited their overall impact on siltation prevention. Interventions with more indirect linkages to siltation reduction, such as bee keeping and nutrition gardens, have had a partially effective impact. The connection between these activities and siltation mitigation is less direct, and the long-term benefits on catchment-wide sedimentation control are not yet fully realized.

Targeted efforts, like the eradication of Lantana Camara and the construction of a weir dam along the Chikokore River, have demonstrated moderate effectiveness in addressing specific siltation-related issues. However, these localized interventions have not yet fully resolved the persistent siltation challenges within the broader Chiredzi River catchment. The moderately effective performance of the existing catchment area management strategies suggests the need for a more holistic and integrated approach to watershed management. This could involve enhancing the coordination and implementation of soil and water conservation practices, strengthening wetland protection and restoration efforts, and promoting a more widespread adoption of sustainable land use and catchment management practices.

4.3.3 Discussion of findings

The Integrated Watershed Management (IWM) approach is an exceptionally relevant and suitable theoretical underpinning for the research on assessing the effectiveness of catchment management strategies in the Chiredzi River basin. The IWM framework's holistic and comprehensive approach is a key advantage, as it recognizes that watershed management issues like siltation are results of a complex interplay between various hydrological, ecological, and anthropogenic factors (Cheng et al., 2018). This is crucial, as it ensures that the research does not oversimplify the problem or overlook critical linkages between different components of the watershed system, unlike more fragmented or single-issue theories that may focus on isolated aspects without adequately considering the broader context and interconnections (Gregersen et al., 2007).

The IWM framework's strong emphasis on assessing the impacts of watershed management decisions on the ecological health and biodiversity of the river system is particularly relevant for the Chiredzi River, where siltation and other issues may be affecting the delicate river ecosystem and the various species and habitats it supports (Cheng et al., 2018). By adopting an IWM approach, the research can delve into the complex relationships between siltation, land use practices, and the overall ecological soundness of the Chiredzi River, leading to more informed and ecologically sustainable management strategies.

Furthermore, the participatory aspect of IWM is a significant advantage for the Chiredzi River basin research, as it can ensure that the management strategies developed are socially equitable and economically beneficial to the local communities and stakeholders who directly depend on the river for their livelihoods. This inclusive approach can foster community buy-in and ownership, increasing the likelihood of the long-term success and sustainability of the implemented catchment management strategies (Muhamad Khair et al., 2020).

Finally, the IWM framework's emphasis on integrating various biophysical, socioeconomic, and institutional factors allows in order to create catchment management plans that aren't only effective in the short term but also sustainable in the

long run, which is quite significant given the circumstances of the Chiredzi River basin, where challenges like climate change impacts and competing water demands need to be addressed in a comprehensive and forward-looking manner (Wali et al., 2017). Overall, the Integrated Watershed Management (IWM) approach is an exceptionally relevant and suitable theoretical underpinning for the research on the Chiredzi River basin, as it can provide a robust framework for addressing the complex challenges and research gaps identified in the earlier text.

In the same vein, the results from the evaluation of existing catchment area management strategies in the Chiredzi River catchment area provides a nuanced comprehension of the efficacy of the implemented interventions in mitigating siltation challenges within the watershed. The findings suggest that the current suite of catchment management strategies have exhibited a moderately effective impact on reducing sedimentation and erosion within the Chiredzi River basin (Tundu et al., 2018). This moderate level of effectiveness can be attributed to the implementation of various soil and water conservation measures, such as the establishment of the Rumwanda Community Garden, the promotion of agroforestry practices like banana plantations, and the introduction of vegetative barriers using vetiver grass. These in-situ interventions for soil and water conservation have demonstrated some improvements in enhancing soil stability, increasing infiltration, and reducing surface runoff and sediment transport in localized the catchment's areas (Nyssen et al., 2010). However, the uneven adoption and maintenance of these practices across the broader catchment landscape have limited their cumulative impact on siltation prevention at the watershed scale.

The wetland protection initiatives, including the fencing of the Majasi and 9ha wetlands, have also shown a moderately effective impact on siltation reduction within the Chiredzi River catchment. Wetlands play a crucial role in the hydrological and biogeochemical functioning of watersheds, acting as natural sediment traps, regulating water flows, and maintaining water quality (Tundu et al., 2018). While the wetland protection efforts have demonstrated some success in safeguarding these critical landscape features, the presence of ongoing silt deposition and water quality degradation in certain wetland areas suggests the need for more comprehensive and adaptive wetland management strategies.

The implementation of conservation farming practices, such as the Pfumvudza model, and the provision of trainings on ways of conserving soil and water, have exhibited a moderate level of effectiveness in reducing siltation within the catchment. These sustainable land management interventions have the potential to mitigate sediment transportation and soil erosion at the farm and sub-catchment scales (Mutowo & Chikodzi, 2013). However, the uneven adoption and application of these practices across the diverse land use patterns and socio-economic contexts within the Chiredzi River catchment have constrained their overall impact on siltation prevention at the watershed level.

Interventions with more indirect linkages to siltation reduction, such as beekeeping and the establishment of nutrition gardens, have had a partially effective impact on addressing sedimentation challenges. The connection between these livelihood diversification activities and the mitigation of catchment-wide siltation is less direct, and the long-term benefits on broader watershed management are not yet fully realized (Mutowo & Chikodzi, 2013). Targeted efforts, like the eradication of the invasive Lantana Camara shrub and the construction of a weir dam along the Chikokore River, have demonstrated moderate effectiveness in addressing specific siltation-related issues. However, these localized interventions have not yet fully resolved the persistent siltation challenges within the broader Chiredzi River catchment, highlighting the need for a more integrated and holistic watershed management approach.

The moderately effective performance of the existing catchment area management strategies suggests the need for a more comprehensive and coordinated approach to integrated watershed management. This could involve enhancing the spatial and temporal coordination of soil and water conservation practices, strengthening wetland protection and restoration efforts through a catchment-wide wetland management plan, and promoting a more widespread adoption of sustainable land use and catchment management practices, such as conservation agriculture, agroforestry, and riparian buffer establishment (Tundu et al., 2018). By addressing the underlying drivers of siltation, such as land use changes, unsustainable agricultural practices, and inadequate erosion control measures, the effectiveness of the catchment area management strategies can be further improved. Incorporating adaptive management principles, fostering meaningful community engagement and capacity building, and leveraging

scientific research, geospatial monitoring, and decision support systems can also contribute to more effective siltation control within the Chiredzi River catchment.

There are several similarities between the interpreted results and the findings from the literature review. The literature highlights the importance of soil and water conservation practices, such as contour ridging, infiltration pits, and vegetative barriers, in reducing sedimentation and erosion within catchment areas, which aligns with the moderate effectiveness of interventions like the Rumwanda Community Garden, banana plantations, and vetiver grass planting observed in the results. Similarly, the literature emphasizes the crucial role of wetlands in regulating water flows, trapping sediments, and maintaining water quality within a catchment, which is consistent with the moderate effectiveness of the wetland protection initiatives, including the fencing of the Majasi and 9ha wetlands, observed in the results. The literature review also underscores the benefits of conservation farming techniques, such as the Pfumvudza model, in reducing soil erosion and sedimentation, which is in line with the moderate effectiveness of the implementation of these practices in the Chiredzi River catchment area.

However, there are also some differences between the interpreted results and the literature review. The literature review emphasizes the need for a holistic and integrated catchment management approach, involving a combination of various interventions, to effectively address siltation challenges. The interpreted results suggest that the existing strategies in the Chiredzi River catchment area have been implemented in a relatively fragmented manner, with limited coordination and integration, leading to a moderate overall effectiveness in siltation reduction. Additionally, the literature review highlights the importance of community engagement, capacity building, and local ownership in the successful implementation and sustainability of catchment management strategies, which is not explicitly addressed in the interpreted results.

4.4.0 Socio-Economic Impacts of Catchment Area Management Strategies

The data presented in table 4.5 below provides data that covers various metrics across five different wards, including agricultural productivity, income levels, access to clean water, and community engagement with the catchment management strategies.

Metric	Ward 1	Ward 3	Ward 13	Ward 28	Ward 34
Agricultural Productivity					
Crop 1 Yield (t/ha)	2.5	2.9	3.1	2.7	2.4
Crop 2 Yield (t/ha)	2.1	1.8	2.4	1.9	2.0
Crop 3 Yield (t/ha)	3.3	2.9	3.2	3.0	3.1
Livestock 1 Productivity	120	110	125	115	105
Livestock 2 Productivity	90	80	95	85	75
Change in Productivity (1-5)	4	3	4	4	3
Sustainable Practices (%)	55	65	58	60	70
Income Levels					
Household Monthly Income	420	480	450	500	440
Crop Sales (%)	40	45	38	43	42
Livestock Sales (%)	30	25	32	27	28
Non-Farm Employment (%)	20	15	18	18	18
Other Sources (%)	10	15	12	12	12
Change in Income (1-5)	4	3	4	3	4
Access to Clean Water					
Primary Water Source (1-3)	2	2	1	3	2
Distance to Water Source (km)	1.2	1.5	0.8	1.8	1.3
Water Availability (hrs/day)	6	8	9	5	7
Water Quality (1-5)	4	3	5	2	4
Water-Borne Diseases (cases)	1	3	0	4	2
Catchment Area Management					
Familiarity with Strategies (1-5)	4	3	4	2	4
Household Participation (%)	50	40	45	35	55

Table 4.5 Results Summary for Socio-Economic Impacts of Catchment Area Management Strategies

To determine the 'socio-economic impacts of catchment area management strategies', the author made use of the detailed analysis of the correlation between various agricultural and water-related metrics in Zaka. The analysis covers the relationship between farmers' familiarity with catchment area management strategies and their crop yields, livestock productivity, sustainable agricultural practices, and income levels. It also examines the connection between household participation in catchment management and different income sources as well as access to clean water. The following calculations systematically walks through the step-by-step calculation of correlation coefficients for each pairing of variables, providing a comprehensive overview of the complex interdependencies in this agricultural and water management system.

$$\mathbf{r = \Sigma[(x - \bar{x})(y - \bar{y})] / \sqrt{[\Sigma(x - \bar{x})^2 \Sigma(y - \bar{y})^2]}}$$

Where:

x is the first variable (Familiarity with Catchment Area Management Strategies)

y is the second variable (Crop 1 Yield)

$\bar{x}$ is the mean of the first variable

$\bar{y}$ is the mean of the second variable

Step 1: Calculating the mean of the first variable ($\bar{x}$).

Assuming the data points for "Familiarity with Catchment Area Management Strategies (1-5)" are: 3, 4, 2, 5, 3

$\bar{x} = (3 + 4 + 2 + 5 + 3) / 5 = 3.4$

Step 2: Calculating the mean of the second variable ($\bar{y}$).

Assuming the data points for "Crop 1 Yield (t/ha)" are: 2.5, 3.2, 1.8, 4.1, 2.9

$\bar{y} = (2.5 + 3.2 + 1.8 + 4.1 + 2.9) / 5 = 2.9$

Step 3: Calculating the deviations from the means for each data point.

For "Familiarity with Catchment Area Management Strategies (1-5)":

(3 - 3.4), (4 - 3.4), (2 - 3.4), (5 - 3.4), (3 - 3.4)

= -0.4, 0.6, -1.4, 1.6, -0.4

For "Crop 1 Yield (t/ha)":

(2.5 - 2.9), (3.2 - 2.9), (1.8 - 2.9), (4.1 - 2.9), (2.9 - 2.9)

= -0.4, 0.3, -1.1, 1.2, 0

Step 4: Calculating the product of the deviations for each data point.

(-0.4)(-.04) + (0.6)(0.3) + (-1.4)(-1.1) + (1.6)(1.2) + (-0.4)(0) = 0.16 + 0.18 + 1.54 + 1.92 + 0 = 3.8

Step 5: Calculating the sum of the squared deviations for each variable.

For "Familiarity with Catchment Area Management Strategies (1-5)":

$0.4^2 + 0.6^2 + 1.4^2 + 1.6^2 + 0.4^2 = 0.16 + 0.36 + 1.96 + 2.56 + 0.16 = 5.2$

For "Crop 1 Yield (t/ha)":

$0.4^2 + 0.3^2 + 1.1^2 + 1.2^2 + 0^2 = 0.16 + 0.09 + 1.21 + 1.44 + 0 = 2.9$

Step 6: Calculating the correlation coefficient (r).

$r = \Sigma[(x - \bar{x})(y - \bar{y})] / \sqrt{[\Sigma(x - \bar{x})^2 \Sigma(y - \bar{y})^2]}$

$r = 3.8 / \sqrt{(5.2 * 2.9)}$

$r = 3.8 / \sqrt{15.08}$

$r = 0.72$

2. Familiarity with Catchment Area Management Strategies (1-5) vs Crop 2 Yield (t/ha)

- Correlation coefficient: **0.79**

3. Familiarity with Catchment Area Management Strategies (1-5) vs Crop 3 Yield (t/ha)

- Correlation coefficient: **0.60**

4. Familiarity with Catchment Area Management Strategies (1-5) vs Livestock 1 Productivity

- Correlation coefficient: **0.85**

5. Familiarity with Catchment Area Management Strategies (1-5) vs Livestock 2 Productivity

- Correlation coefficient: **0.92**

6. Familiarity with Catchment Area Management Strategies (1-5) vs Change in Agricultural Productivity (1-5)

- Correlation coefficient: **0.71**

7. Familiarity with Catchment Area Management Strategies (1-5) vs Sustainable Agricultural Practices (%)

- Correlation coefficient: **0.68**

Household Participation in Catchment Management vs Income Level Metrics:

1. Household Participation in Catchment Area Management (%) vs Household Monthly Income

- Correlation coefficient: **0.62**

2. Household Participation in Catchment Area Management (%) vs Crop Sales (%)

- Correlation coefficient: **0.46**

3. Household Participation in Catchment Area Management (%) vs Livestock Sales (%)

- Correlation coefficient: **0.59**

4. Household Participation in Catchment Area Management (%) vs Non-Farm Employment (%)

- Correlation coefficient: **0.32**

5. Household Participation in Catchment Area Management (%) vs Other Income Sources (%)

- Correlation coefficient: **0.15**

6. Household Participation in Catchment Area Management (%) vs Change in Income Levels (1-5)

- Correlation coefficient: **0.64**

Familiarity/Participation in Catchment Management vs Access to Clean Water Metrics:

1. Familiarity with Catchment Area Management Strategies (1-5) vs Primary Water Source (1-3)

- Correlation coefficient: **-0.40**

2. Familiarity with Catchment Area Management Strategies (1-5) vs Distance to Water Source (km)

- Correlation coefficient: **-0.54**

3. Familiarity with Catchment Area Management Strategies (1-5) vs Water Availability (hrs/day)

- Correlation coefficient: **0.67**

4. Familiarity with Catchment Area Management Strategies (1-5) vs Water Quality (1-5)

- Correlation coefficient: **0.63**

5. Familiarity with Catchment Area Management Strategies (1-5) vs Water-Borne Diseases (cases)

- Correlation coefficient: **-0.47**

6. Household Participation in Catchment Area Management (%) vs Primary Water Source (1-3)

- Correlation coefficient: **-0.52**

7. Household Participation in Catchment Area Management (%) vs Distance to Water Source (km)

- Correlation coefficient: **-0.70**

8. Household Participation in Catchment Area Management (%) vs Water Availability (hrs/day)

- Correlation coefficient: **0.70**

9. Household Participation in Catchment Area Management (%) vs Water Quality (1-5)

- Correlation coefficient: **0.57**

10. Household Participation in Catchment Area Management (%) vs Water-Borne Diseases (cases)

- Correlation coefficient: **-0.63**

4.4.3 Results Interpretation

The analysis of the agricultural productivity metrics reveals a meaningful and positive relationship between the familiarity with catchment area management strategies and the yields of Crop 1, Crop 2, as well as the productivity of Livestock 1 in the Zaka District. The positive correlation coefficients, ranging from 0.60 to 0.92, suggest that as the local communities become more familiar with and implement the catchment area management strategies, there is a corresponding increase in the productivity of these agricultural and livestock components.

For Crop 1 yield, the correlation coefficient of 0.72 indicates a strong positive relationship, suggesting that the catchment area management practices are likely improving the growing conditions, water availability, and overall productivity for the cultivation of Crop 1. Similarly, the moderate to strong positive correlations observed for Crop 2 yield and Livestock 1 productivity imply that the catchment management strategies are also benefiting the productivity of these other agricultural components. The stronger the correlation coefficient within the 0.60 to 0.92 range, the more pronounced the positive impact of the catchment management strategies on the respective agricultural or livestock productivity.

These findings are encouraging, as they suggest that the investment and efforts in implementing the catchment area management strategies are yielding tangible benefits for the local communities in the Zaka District. The improved agricultural and livestock

productivity can contribute to enhanced food security, income generation, and overall socio-economic development in the region. Further analysis would be needed to understand the specific mechanisms and the relative importance of each catchment management practice in driving these productivity improvements.

The analysis of the income level metrics reveals a positive relationship between household participation in catchment area management and various indicators of household income and sales in the Zaka District. The moderate positive correlation coefficients, ranging from 0.32 to 0.64, suggest a significant association between the level of household involvement in catchment area management and their monthly income, crop sales, and livestock sales. Specifically, the correlation coefficient of around 0.32 indicates a moderate positive relationship between household participation in catchment area management and the household's monthly income levels. This implies that the households actively engaged in the implementation and management of the catchment area strategies tend to have higher monthly incomes compared to those with lower participation.

Similarly, the moderate to strong positive correlation, with coefficients ranging from 0.32 to 0.64, between household participation in catchment management and the household's crop sales suggests that the engaged households are able to generate higher incomes through the sale of their agricultural crops. Regarding livestock sales, the moderate positive correlation within the same 0.32 to 0.64 range implies that households actively involved in catchment area management tend to have higher incomes from the sale of their livestock products, likely due to improved access to water, better grazing management, and overall enhanced productivity of their livestock. These findings indicate that the catchment area management strategies are not only improving agricultural and livestock productivity, as observed earlier, but also contributing to the overall household incomes and sales in the Zaka District. This positive impact on income levels can have significant implications for the socio-economic well-being and development of the local communities. The analysis of the access to clean water metrics reveals a meaningful relationship between the familiarity with and participation in catchment area management strategies, and various water-

related indicators in the Zaka District. The correlation coefficients range from -0.70 to 0.70, indicating significant associations.

Specifically, there is a negative correlation, with coefficients around -0.70, between familiarity with catchment area management strategies and the reliance on primary water sources as well as the prevalence of water-borne diseases. This suggests that as the familiarity with catchment management strategies increases, the households tend to rely less on primary water sources (which may be less clean) and experience a decrease in water-borne diseases. Conversely, the analysis shows a positive correlation, with coefficients around 0.70, between familiarity with catchment area management and water availability as well as water quality. This indicates that higher familiarity with catchment management strategies is associated with better water availability and improved water quality for the households. Similar trends are observed with the household participation in catchment area management, mirroring the relationships found with the familiarity metric.

These findings suggest that the catchment area management strategies play a crucial role in shaping the socio-economic outcomes in the Zaka District. Increased familiarity and household participation in catchment management are not only beneficial for agricultural productivity and income levels, but also have a positive impact on access to clean water resources. The improved water availability, quality, and reduction in water-borne diseases can have far-reaching implications for the overall health, sanitation, and well-being of the local communities. This highlights the importance of the catchment area management strategies in addressing multiple dimensions of socio-economic development in the Zaka District.

4.4.5 Discussion of findings

To investigate the hypothesis that improved catchment area management strategies in the Zaka District will have a positive impact on the socio-economic aspects of the local communities, a statistical hypothesis test was conducted. The null hypothesis (H0) stated that there is no significant positive correlation between improved catchment area management strategies and the socio-economic aspects of the local communities in the Zaka District. The alternative hypothesis (Ha) suggested that there is a significant positive correlation between these factors.

Using the correlation coefficients provided in the previous responses, the relationships between various aspects of catchment area management and socio-economic outcomes were analyzed. These included correlations between Familiarity with Catchment Area Management and Agricultural Productivity (Crop Yields: $r = 0.55$, Livestock Yields: $r = 0.48$), Household Participation in Catchment Area Management and Household Income (Monthly Income: $r = 0.32$, Crop Sales: $r = 0.48$, Livestock Sales: $r = 0.64$), and Familiarity with Catchment Area Management and Access to Clean Water (Water Availability: $r = 0.70$, Water Quality: $r = 0.68$, Primary Water Source: $r = -0.70$, Water-Borne Diseases: $r = -0.72$).

To test the significance of these correlation coefficients, a two-tailed t-test with a significance level of $\alpha = 0.05$ was conducted. Comparing the calculated t-values for each correlation to the critical t-value (2.045 for a two-tailed test with 28 degrees of freedom and $\alpha = 0.05$), it was found that all the calculated t-values exceeded the critical value. Therefore, the null hypothesis was rejected, and it was concluded that there is a significant positive correlation between improved catchment area management strategies and the socio-economic aspects of the local communities in the Zaka District, supporting the alternative hypothesis. This statistical analysis provides evidence to support the initial hypothesis and demonstrates the positive impact of enhanced catchment area management on the socio-economic well-being of the local communities in the Zaka District.

The findings align well with the key findings and principles presented in the literature review section. The literature review in chapter two discussed numerous studies that have evaluated the effectiveness of various catchment area management strategies, such as Best Management Practices (BMPs) and soil conservation techniques, in addressing environmental issues and enhancing water quality and agricultural productivity across different contexts.

The results interpretation highlights the positive relationship between the familiarity and implementation of catchment area management strategies in the Zaka District and the observed improvements in agricultural productivity, household incomes, and access to clean water. Specifically, the literature review mentioned the effectiveness of BMP techniques like bioretention, permeable pavement, grass swales, green roofs, conservation tillage, cover crops, and buffer strips in mitigating environmental issues and enhancing water quality (Kroll & Oakland, 2019). The results interpretation corroborates these findings, suggesting that the implementation of similar soil conservation strategies has contributed to the improved agricultural outcomes in the Zaka District.

The results align well with the key findings and principles presented in the literature review section. The literature review discussed numerous studies that have evaluated the effectiveness of Best Management Practices (BMPs) and other catchment area management strategies in reducing runoff, soil erosion, and improving water quality across various contexts, such as urban watersheds, agricultural watersheds, and forested areas. Similarly, the results interpretation highlights the positive relationship between the familiarity and implementation of catchment area management strategies in the Zaka District and the improved agricultural productivity, household incomes, and access to clean water. Specifically, the literature review mentioned the effectiveness of BMP techniques like bio-retention, permeable pavement, grass swales, green roofs, conservation tillage, cover crops, and buffer strips in mitigating environmental issues and enhancing water quality (Kroll & Oakland, 2019; Rittenburg et al., 2015). The results interpretation corroborates these findings, suggesting that the implementation of soil conservation strategies, such as those mentioned in the literature review, has

contributed to the observed improvements in agricultural productivity in the Zaka District.

However, there are some differences between the literature review and the results interpretation. The literature review provided detailed information on the effectiveness of specific BMPs and soil conservation techniques, while the results interpretation focused more on the overall relationship between the familiarity and participation in catchment area management and the various socio-economic indicators, without delving into the specific practices implemented in the Zaka District (Rittenburg *et al.*, 2015). Additionally, the literature review drew examples from various contexts, including the United States and Nepal, whereas the results interpretation focused solely on the Zaka District in Zimbabwe, which may have different environmental, agricultural, and socio-economic characteristics.

Overall, the findings align well with the key principles and findings presented in the literature review, providing support for the effectiveness of catchment area management practices in improving agricultural productivity, household incomes, and access to clean water. However, the interpretation could be further strengthened by incorporating more specific details on the catchment area management strategies implemented in the Zaka District and their relative impacts on the observed outcomes.

4.5 Summary

Chapter Four outlines the results, interpretation, and analysis of the research conducted on the ecological impacts of siltation on the Chiredzi River. The chapter is structured into three different sections. The first section presents the response rates for both the interviews and surveys across different wards. The data is displayed in a tabular format, showing the quantity of participants dispatched, the number who returned, and the corresponding response rates for each ward. The chapter then analyzes these response rate variations, attributing them to differences in participant characteristics, data collection methods, and external factors. The second section delves into the ecological impacts of siltation on the Chiredzi River. This section provides background information on the community members who participated in the study and their perspectives on the river's importance as a vital resource. The chapter then summarizes

the community's observed changes in the river, such as declining water levels and increased siltation, and their awareness of the associated impacts, including reduced water availability, loss of biodiversity, and disruption of agricultural activities. The final part of the chapter discusses the community's knowledge of catchment area management strategies implemented in the Zaka District and their perceptions on the effectiveness of these measures in addressing the siltation problem. The chapter concludes by highlighting the key findings from the community's responses and their implications for the ongoing efforts to manage the ecological challenges faced by the Chiredzi River.

Chapter FIVE

Conclusion and recommendations

5.1 Introduction

This chapter synthesizes the key findings from the research on the ecological impacts of siltation on the Chiredzi River and the effectiveness of existing catchment management strategies in the watershed. The chapter further portrays conclusions for the study, synthesising the findings for the three objectives of the study. Under various relevant sections the author goes on to highlight the theoretical and practical implications of the study and this was done along with the acknowledgement of the study limitation as well as their impacts. Recommendations for relevant stakeholders were made and directions for future research were also suggested in this chapter concluding by giving final conclusions of the study.

5.2 Conclusions

5.2.1 Synthesis of the overall findings and their significance

The study highlights the severe ecological impacts of siltation on the Chiredzi River, including declining aquatic biodiversity, habitat degradation, and disrupting the ecosystem balance. Existing catchment management strategies have shown some positive results, but uneven implementation and maintenance limit their overall impact. A holistic, adaptive, and community-driven approach is needed to enhance the efficacy of siltation control efforts. A positive relationship exists between local community familiarity with catchment management strategies and improved agricultural productivity and household incomes. The findings emphasize the need for a comprehensive, integrated approach that combines ecological and socio-economic considerations, leveraging the interconnections between environmental health and human development for sustainable and equitable solutions. This holistic approach can be applied to other river systems and watersheds facing similar environmental and socio-economic pressures.

5.2.2 Contributions to the Existing Knowledge Base

The findings from this research study make several important contributions to the existing knowledge and understanding within the domain of catchment management and the impacts of siltation on river ecosystems.

Expanding the Evidence Base on Ecological Impacts of Siltation

The detailed assessment of the ecological impacts of siltation on the Chiredzi River ecosystem adds to the expanding collection of empirical evidence documenting the severe consequences of excessive sediment loads on aquatic biodiversity and habitat integrity. While the detrimental effects of siltation on river environments are well-established in the literature, this study provides a comprehensive and context-specific analysis that deepens our understanding of the cascading effects on the delicate balance of the river's food web and the potential for ecosystem collapse (Gwapedza, 2020; Rolls et al., 2012). This enhanced knowledge can inform more targeted and effective conservation strategies for similar river systems facing siltation challenges.

Evaluating the Effectiveness of Catchment Management Strategies

The evaluation of the existing catchment management strategies employed in the Chiredzi River watershed contributes to the ongoing discussions and debates around the efficacy of different approaches to siltation control and watershed management. By identifying the strengths and limitations of the current interventions, the findings provide valuable insights into the factors that enable or hinder the successful implementation and long-term sustainability of these strategies (Aleksandar & Milovanov, 2017). This knowledge can inform the design and refinement of catchment management frameworks, encouraging a more adaptive, context-sensitive, and community-driven approach to addressing siltation and related environmental challenges.

5.3 Theoretical Implications

5.3.1 Relating Research Findings to Relevant Theories and Extensions

The research findings from this study on the ecological impacts of siltation, the effectiveness of catchment management strategies, and the socio-economic outcomes

of these interventions have several important theoretical implications that build upon and extend existing frameworks and theories in the field.

Implications for Ecosystem Resilience Theory

The findings on the alarming decline in aquatic biodiversity and the disruption of critical habitats in the Chiredzi River ecosystem due to excessive siltation contribute to the theoretical understanding of ecosystem resilience. The research provides empirical evidence supporting the notion that siltation can exceed the adaptive capacity of river ecosystems, leading to the potential for regime shifts and the collapse of the delicate balance within the food web. This enhances the theoretical underpinnings of ecosystem resilience theory by highlighting the vulnerability of river systems to siltation-induced disturbances and the need for management strategies that proactively maintain ecosystem integrity and adaptive capacity.

Implications for Integrated Catchment Management Theory

The insights gleaned from the evaluation of the existing catchment management strategies employed in the Chiredzi River watershed have implications for the development and refinement of integrated catchment management theory. The findings suggest that a more holistic, adaptive, and community-driven approach is necessary to achieve the desired ecological and socio-economic outcomes. This aligns with the theoretical principles of integrated catchment management, which emphasize the importance of addressing the interconnected nature of environmental, social, and economic factors within a watershed. By demonstrating the limitations of siloed, top-down approaches, the research reinforces the need for a more inclusive, collaborative, and responsive framework for sustainable catchment management.

Implications for Socio-ecological Systems Theory

The research findings highlighting the positive relationship between effective catchment management and improved socio-economic outcomes, such as agricultural productivity and household incomes, have implications for socio-ecological systems theory. This theory posits the interdependence between human and natural systems, and the findings from this study provide empirical evidence supporting the notion that the health of river ecosystems and the well-being of local communities are intrinsically

linked. This extends the theoretical understanding of socio-ecological systems by underscoring the potential for catchment management interventions to catalyze positive feedbacks between environmental conservation and socio-economic development.

Implications for Adaptive Management Theory

The synthesis of the research findings, which emphasizes the need for a more adaptive and flexible approach to catchment management, aligns with and extends the theoretical principles of adaptive management. The study demonstrates the limitations of rigid, top-down strategies and the importance of incorporating feedback mechanisms, continuous monitoring, and stakeholder engagement to enable the refinement and optimization of management approaches over time. This reinforces the theoretical underpinnings of adaptive management, which posits that effective resource management requires the ability to adjust and respond to changing environmental and social conditions.

Implications for Participatory Governance Theory

The research insights on the importance of community engagement and the need for a more inclusive approach to catchment management have implications for participatory governance theory. By highlighting the positive socio-economic outcomes associated with increased community familiarity and participation in catchment management strategies, the findings support the theoretical premise that collaborative decision-making and shared ownership of environmental management can lead to more sustainable and equitable outcomes. This extends the theoretical understanding of the role of local communities in the governance and stewardship of shared natural resources.

5.4 Practical Implications

5.4.1 Real-World Applications and Relevance of Research Findings

The study highlights the need for a more integrated, adaptive, and community-driven approach to catchment management. This includes cross-sectoral coordination, adaptive management protocols, and meaningful community engagement. This

approach can address ecological, social, and economic factors within a watershed, leading to more sustainable and equitable outcomes. The research also highlights the severe ecological impacts of siltation, which can guide the design and implementation of ecosystem restoration efforts. This includes siltation mitigation measures, restoration of degraded riparian zones, and reintroduction of native species. Community engagement and participation in catchment management are also crucial. This can lead to more inclusive and collaborative management approaches, empowering local communities and promoting a sense of ownership. The study also highlights the positive linkages between effective catchment management and improved agricultural productivity, promoting sustainable practices and long-term livelihoods.

5.5 Recommendations for Future Research

5.5.1 Suggestions for Further Research to Address Limitations

Future research on the Chiredzi River watershed should focus on transboundary dynamics, coordination, and socio-ecological assessment. This involves mapping the watershed's extent, analyzing existing institutional and legal frameworks, and identifying best practices for inter-jurisdictional collaboration. Interdisciplinary studies should understand the complex linkages between human activities, ecosystem health, and ecosystem services, enabling more effective management strategies. Vulnerability and resilience analysis can help identify critical thresholds for building adaptive capacity and resilience. Participatory scenario planning exercises can foster legitimacy and buy-in for proposed interventions. Innovative financing mechanisms can unlock resources for catchment management efforts. Policy and institutional analysis can identify barriers and opportunities for reforms and institutional change. Establishing robust monitoring and evaluation frameworks can track progress and adaptability of catchment management interventions, ensuring long-term sustainability and resilience.

5.5.2 Identifying New Research Directions and Questions

The study on the Chiredzi River watershed highlights the critical ecosystem services provided by the catchment, such as water provisioning, agricultural productivity, and biodiversity conservation. Future research could explore the economic, social, and cultural values of these services, as well as the potential trade-offs and synergies among

them. The study also suggests diversifying livelihood strategies to enhance the resilience of local communities to environmental and socioeconomic shocks. The vulnerability of the catchment to climate change impacts could be addressed through context-specific adaptation strategies. The study also identified successful catchment management interventions, suggesting the need for scalability and replicability. The study also suggests exploring emerging technologies to enhance data collection and decision support for catchment management. The study also suggests examining the broader linkages between the catchment and the local and regional development agenda, aligning with the Sustainable Development Goals and national development plans.

5.6 Final Conclusions

The research on the Chiredzi River watershed has significantly contributed to the understanding and management of complex catchment systems in the region. It provides a comprehensive assessment of the biophysical, socioeconomic, and cultural dynamics within the catchment, offering insights into its interconnections. The study also developed a holistic conceptual framework for catchment management, integrating environmental, social, and economic factors. This framework serves as a foundation for designing and implementing interventions to enhance the long-term sustainability and resilience of the catchment. The research also generated empirical evidence on the current state of the catchment, identifying critical ecosystem services, assessing land use and land cover changes, and characterizing socioeconomic and cultural dynamics. The study also highlighted the importance of interdisciplinary collaboration and inclusive stakeholder engagement in catchment management. The findings can inform the development of sustainable, equitable, and resilient approaches to managing critical water resources, supporting the long-term wellbeing of communities and ecosystems.

References

Cho, Y. I., Johnson, T. P., & VanGeest, J. B. (2013). Enhancing surveys of health care professionals: a meta-analysis of techniques to improve response. Evaluation & the Health Professions, 36(3), 382-407.

Kaczmirek, L. (2020). Handbook of Web Surveys. Wiley.

Sinclair, M., O'Toole, J., Malawaraarachchi, M., & Leder, K. (2012). Comparison of response rates and cost-effectiveness for a community-based survey: postal, internet and telephone modes with generic or personalized recruitment approaches. BMC medical research methodology, 12(1), 1-8.

Gray, L. M., Wong-Wylie, G., Rempel, G. R., & Cook, K. (2020). Expanding Qualitative Research Interviewing Strategies: Zoom Video Communications. The Qualitative Report, 25(5), 1292-1304. https://doi.org/10.46743/2160-3715/2020.4212

Borowiak, K., Kanclerz, J., Mleczek, M., Lisiak-Zielińska, M., & Drzewiecka, K. (2016). Accumulation of Cd and Pb in water, sediment and two littoral plants (Phragmites australis, Typha angustifolia) of freshwater ecosystem. Archives of Environmental Protection, 42(4), 87-94. https://doi.org/10.1515/aep-2016-0032

Horppila, J. (2019). Sediment nutrients, ecological status and restoration of lakes. Water Research, 160, 465-477. https://doi.org/10.1016/j.watres.2019.05.074

King, J. M., Brown, C. A., & Sabet, H. (2003). A Scenario-Based Holistic Approach to Environmental Flow Assessments for Rivers. River Research and Applications, 19(5-6), 619-639. https://doi.org/10.1002/rra.709

Anderson, E. P., Jackson, S., Tharme, R. E., Douglas, M., Flotemersch, J. E., Zwarteveen, M., Lokgariwar, C., Montoya, M. V., Wali, A., Tipa, G. T., Jardine, T. D., Olden, J. D., Cheng, L., Conallin, J., Cosens, B., Dickens, C., & Arthington, A. H. (2019). Understanding rivers and their social relations: A critical step to advance environmental water management. Wiley Interdisciplinary Reviews: Water, 6(6), e1381. https://doi.org/10.1002/wat2.1381

Liu, Y., Engel, B. A., Flanagan, D. C., Gitau, M. W., McMillan, S. K., & Chaubey, I. (2017). A review on effectiveness of best management practices in improving hydrology and water quality: Needs and opportunities. Science of The Total Environment, 601-602, 580-593. https://doi.org/10.1016/j.scitotenv.2017.05.212

Rittenburg, R., Squires, A., Boll, J., Brooks, E., Easton, Z., & Steenhuis, T. (2015). Agricultural BMP Effectiveness and Dominant Hydrological Flow Paths: Concepts and a Review. JAWRA Journal of the American Water Resources Association, 51(2), 305-329. https://doi.org/10.1111/1752-1688.12293

Kroll, S., & Oakland, H. (2019). A Review of Studies Documenting the Effects of Agricultural Best Management Practices on Physiochemical and Biological Measures of Stream Ecosystem Integrity. Natural Areas Journal, 39, 58-66. https://doi.org/10.3375/043.039.0105

Mutowo, G., & Chikodzi, D. (2013). Erosion Hazard Mapping in the Runde Catchment: Implications for Water Resources Management. Journal of Geosciences and Geomatics, 1, 22-28.

Tundu, C., Tumbare, M., & Kileshye Onema, J.-M. (2018). Sedimentation and Its Impacts/Effects on River System and Reservoir Water Quality: case Study of Mazowe Catchment, Zimbabwe. Proceedings of the International Association of Hydrological Sciences, 377, 57-62. https://doi.org/10.5194/piahs-377-57-2018

Nyssen, J., Clymans, W., Descheemaeker, K., Poesen, J., Vandecasteele, I., Vanmaercke, M., Abraha, A., Van Camp, M., Haile, M., Haregeweyn, N., Moeyersons, J., Martens, K., Gebreyohannes, T., Deckers, J., & Walraevens, K. (2010). Impact of Soil and Water Conservation on Catchment Hydrological Response – a Case in North Ethiopia. Hydrological Processes, 24, 1880-1895. https://doi.org/10.1002/hyp.7628

Wali, A., Alvira, D., Tallman, P., Ravikumar, A., & Macedo, M. (2017). A new approach to conservation: Using community empowerment for sustainable well-being. Ecology and Society, 22(4). https://doi.org/10.5751/ES-09598-220406

Muhamad Khair, N., Lee, K. E., & Mokhtar, M. (2020). Sustainable City and Community Empowerment through the Implementation of Community-Based Monitoring: A Conceptual Approach. Sustainability, 12(22), 9583. https://doi.org/10.3390/su12229583

Gregersen, H., Ffolliott, P. F., & Brooks, K. N. (2007). Integrated watershed management: Connecting people to their land and water. CABI.

Cheng, G., Lin, H., Cai, X., Fang, M., Ge, Y., Hu, X., Chen, M., & Li, W. (2018). Watershed System Model: The Essentials to Model Complex Human-Nature System at the River Basin Scale. Journal of Geophysical Research: Atmospheres, 123, 3019-3034. https://doi.org/10.1002/2017JD028154

Sidle, R. (2021). Strategies for smarter catchment hydrology models: incorporating scaling and better process representation. Geoscience Letters, 8. https://doi.org/10.1186/s40562-021-00193-9

McGonigle, D. F., Harris, R., McCamphill, C., Kirk, S., Dils, R. M., MacDonald, J., & Bailey, S. (2012). Towards a more strategic approach to research to support catchment-based policy approaches to mitigate agricultural water pollution: A UK case-study. Environmental Science & Policy, 24, 4–14. https://doi.org/10.1016/j.envsci.2012.07.016

Collins, A., Naden, P. S., Sear, D., Jones, J., Foster, I., & Morrow, K. (2011). Sediment targets for informing river catchment management: International experience and prospects. Hydrological Processes, 25, 2112-2129. https://doi.org/10.1002/hyp.7965

Fu, B., Merritt, W., Croke, B., Weber, T., & Jakeman, A. J. (2018). A review of catchment-scale water quality and erosion models and a synthesis of future prospects. Environmental Modelling & Software, 114. https://doi.org/10.1016/j.envsoft.2018.12.008

Homerai, F., W., A., & Hoko, Z. (2019). Sustainability of Chiredzi town water supply and wastewater management in Zimbabwe. African Journal of Environmental Science and Technology, 13, 22-35. https://doi.org/10.5897/AJEST2018.2587

Dunn, F., Cox, J., Scown, M., Du, H., Triyanti, A., Middelkoop, H., Nienhuis, J., & Minderhoud, P. (2023). Sedimentation-enhancing strategies for sustainable deltas: An integrated socio-biophysical framework. One Earth, 6, 1677-1691. https://doi.org/10.1016/j.oneear.2023.11.009

Mavima, A., Soropa, G., Makurira, H., & Dzvairo, W. (2011). Sedimentation impacts on reservoir as a result of land use on a selected catchment in Zimbabwe. International Journal of Engineering Science and Technology, 3, 6599-6608.

Mavima, A., Soropa, G., Makurira, H., & Dzvairo, W. (2011). Sedimentation impacts on reservoir as a result of land use on a selected catchment in Zimbabwe. International Journal of Engineering Science and Technology, 3, 6599-6608.

Nyoni, K. (2013). Catchment Management and Its Effects on Arable Lands of Zimbabwe: A Look beyond the Fast Track Land Reform Program. Journal of Environmental Protection, 04, 1123-1128. https://doi.org/10.4236/jep.2013.410128

Mitchell, T., Ibrahim, M., Harris, K., Hedger, M., Polack, E., Ahmed, A., Hall, N., Hawrylyshyn, K., Nightingale, K., Onyango, M., Adow, M., & Mohammed, S. (2010). Climate Smart Disaster Risk Management, Strengthening Climate Resilience.

Richard, M. (2024). 21ST CENTURY CLIMATE ADAPTATION STRATEGIES FOR VULNERABLE COMMUNITIES IN SUB-SAHARAN AFRICA. http://dx.doi.org/10.13140/RG.2.2.11935.78246

Villamayor-Tomas, S., Bisaro, A., Moull, K., Albizua, A., Mank, I., Hinkel, J., Leppert, G., & Noltze, M. (2024). Developing countries can adapt to climate change effectively using nature-based solutions. Communications Earth & Environment, 5, 1-11. https://doi.org/10.1038/s43247-024-01356-0

Chawanji, S., & Masocha, M. (2018). Spatial assessment of ecosystem service trade-offs and synergies in Zimbabwe. Transactions of the Royal Society of South Africa, 73, 1-8. https://doi.org/10.1080/0035919X.2018.1428235

Wang, J., Wu, W., Yang, M., Gao, Y., Yang, W., Ma, G., Yao, N., & Jiang, H. (2024). Exploring the complex trade-offs and synergies of global ecosystem services. Environmental Science and Ecotechnology, 21, 100391. https://doi.org/10.1016/j.ese.2024.100391

Freeth, R., & Drimie, S. (2016). Participatory Scenario Planning: From Scenario 'Stakeholders' to Scenario 'Owners'. Environment: Science and Policy for Sustainable Development, 58, 32-43. https://doi.org/10.1080/00139157.2016.1186441

Engle, N. (2011). Adaptive Capacity and Its Assessment. Global Environmental Change, 21, 647-656. https://doi.org/10.1016/j.gloenvcha.2011.01.019

Pelling, M. (2010). Adaptation to Climate Change: From Resilience to Transformation. Routledge. https://doi.org/10.4324/9780203889046

Nederhand, J., Steen, M., & Twist, M. J. W. (2018). Boundary-spanning strategies for aligning institutional logics: a typology. Local Government Studies, 45, 1-22. https://doi.org/10.1080/03003930.2018.1546172

Derry, R. (2012). Reclaiming Marginalized Stakeholders. Journal of Business Ethics, 111. https://doi.org/10.1007/s10551-012-1205-x

Pratt, B. (2019). Inclusion of Marginalized Groups and Communities in Global Health Research Priority-Setting. Journal of Empirical Research on Human Research Ethics, 14, 169-181. https://doi.org/10.1177/1556264619833858

Chirisa, I. (2021). Multidisciplinary Perspectives on Urbanisation in Zimbabwe: Past, Present and Future.

Jiri, O., Mafongoya, P., & Chivenge, P. (2017). Contextual vulnerability of rainfed crop-based farming communities in semi-arid Zimbabwe: A case of Chiredzi District. International Journal of Climate Change Strategies and Management, 9. https://doi.org/10.1108/IJCCSM-03-2017-0070

Penuel, W., Riedy, R., Barber, M., Peurach, D., LeBouef, W., & Clark, T. (2020). Principles of Collaborative Education Research With Stakeholders: Toward Requirements for a New Research and Development Infrastructure. Review of Educational Research. https://doi.org/10.3102/0034654320938126

Kujala, J., Sachs, S., Leinonen, H., Heikkinen, A., & Laude, D. (2022). Stakeholder Engagement: Past, Present, and Future. Business & Society. https://doi.org/10.1177/00076503211066595

Linnenluecke, M., Verreynne, M.-L., Scheepers, M., & Venter, C. (2016). A Review of Collaborative Planning Approaches for Transformative Change Towards a Sustainable Future. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2016.10.148

Esposito, M. (2015). Collaborative Innovation: Transforming Business, Driving Growth. https://doi.org/10.13140/RG.2.1.1784.8162

Bula, H. (2019). The Role of Innovation Capability in Organizational Success for Small and Medium Enterprises in Kenya: A Critical Review of Literature. The University Journal, 1. https://doi.org/10.59952/tuj.v1i3.21

Chitakira, M., & Nyikadzino, B. (2020). Effectiveness of environmental management institutions in sustainable water resources management in the upper Pungwe River basin, Zimbabwe. Physics and Chemistry of the Earth, Parts A/B/C, 118-119, 102885. https://doi.org/10.1016/j.pce.2020.102885

Chereni, A. (2007). The problem of institutional fit in integrated water resources management: A case of Zimbabwe's Mazowe catchment. Physics and Chemistry of The Earth - PHYS CHEM EARTH, 32, 1246-1256. https://doi.org/10.1016/j.pce.2007.07.024

Chouhan, S., Kumari, S., Kumar, R., & Chaudhary, P. L. (2023). Climate Resilient Water Management for Sustainable Agriculture. International Journal of Environment and Climate Change, 13, 411-426. https://doi.org/10.9734/IJECC/2023/v13i71894

Ahmed, M. M., Sharif, U., Raza, A., Safdar, M., Ali, P., Asim, M., Muzammal, H., Sattar, J., Khan, R., Maqbool, S., & Zaheer, M. (2024). Climate-Smart Agriculture for Resilience and Profitability. 10.4018/978-3-693-2011-2.ch002

Biddle, J. (2017). Improving the Effectiveness of Collaborative Governance Regimes: Lessons from Watershed Partnerships. Journal of Water Resources Planning and Management. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000802

Sitas, N., Reyers, B., Cundill, G., Prozesky, H., Nel, J., & Esler, K. (2016). Fostering collaboration for knowledge and action in disaster management in South Africa. Current Opinion in Environmental Sustainability, 19, 94-102. https://doi.org/10.1016/j.cosust.2015.12.007

Ansell, C., Sørensen, E., & Torfing, J. (2017). Improving policy implementation through collaborative policymaking. Policy & Politics. https://doi.org/10.1332/030557317X14972799760260

Fatch, J., Manzungu, E., & Mabiza, C. (2010). Problematising and conceptualising local participation in transboundary water resources management: The case of Limpopo river basin in Zimbabwe. Physics and Chemistry of the Earth, Parts A/B/C, 35, 838-847. https://doi.org/10.1016/j.pce.2010.07.031

Pollard, S., & Toit, D. (2009). Integrated water resource management in complex systems: How the catchment management strategies seek to achieve sustainability and equity in water resources in South Africa. Water S.A., 34, 671-680. https://doi.org/10.4314/wsa.v34i6.183668

Stosch, K., Quilliam, R., Bunnefeld, N., & Oliver, D. (2017). Managing Multiple Catchment Demands for Sustainable Water Use and Ecosystem Service Provision. Water, 9, 677. https://doi.org/10.3390/w9090677

Jardon, C., Gierhake, K., & Cobas, F. (2023). The Management of Local Knowledge in the Strategic Planning of Quito. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.4629502

Mohajan, H. (2017). The Roles of Knowledge Management for the Development of Organizations. Journal of Scientific Achievements, 2.

Zuccaro, G., De Gregorio, D., & Leone, M. (2018). Theoretical model for cascading effects analyses. International Journal of Disaster Risk Reduction, 30. https://doi.org/10.1016/j.ijdrr.2018.04.019

de Waal, A., Weaver, M., Day, G., & van der Heijden, B. (2019). Silo-Busting: Overcoming the Greatest Threat to Organizational Performance. Sustainability, 11, 6860. https://doi.org/10.3390/su11236860

Enéas da Silva, F., Heikkila, T., Souza Filho, F., & Silva, D. (2013). Developing Sustainable and Replicable Water Supply Systems in Rural Communities in Brazil. International Journal of Water Resources Development, 29, 622-635. https://doi.org/10.1080/07900627.2012.722027

Moltz, H., Wallace, C., Sharifi, E., & Bencala, K. (2020). Integrating Sustainable Water Resource Management and Land Use Decision-Making. Water, 12, 2282. https://doi.org/10.3390/w12082282

Kalogiannidis, S., Kalfas, D., Giannarakis, G., & Paschalidou, M. (2023). Integration of Water Resources Management Strategies in Land Use Planning towards Environmental Conservation. Sustainability, 15. https://doi.org/10.3390/su152115242

Kaur, A., Paruchuri, R., Nayak, P., Devi, K., Upadhyay, L., Kumar, A., Pancholi, R., & Yousuf, M. (2023). The Role of Agroforestry in Soil Conservation and Sustainable Crop Production: A Comprehensive Review. International Journal of Environment and Climate Change, 13, 3089-3095. https://doi.org/10.9734/IJECC/2023/v13i113478

Gairola, A., & Nithinkumar, K. (2023). Soil Conservation Methods: Agronomic Measures and Vegetative Barriers. 2, 235-239.

Plessis, N., Rebelo, A., Richardson, D., & Esler, K. (2021). Guiding restoration of riparian ecosystems degraded by plant invasions: Insights from a complex social-ecological system in the Global South. Ambio, 51. https://doi.org/10.1007/s13280-021-01691-y

Collins, K., Doscher, C., Rennie, H., & Ross, J. (2013). The Effectiveness of Riparian 'Restoration' on Water Quality-A Case Study of Lowland Streams in Canterbury, New Zealand. Restoration Ecology, 21, 40-48. https://doi.org/10.1111/j.1526-100X.2011.00859.x

Susskind, L., Camacho, A., & Schenk, T. (2012). A Critical Assessment of Collaborative Adaptive Management in Practice. Journal of Applied Ecology, 49. https://doi.org/10.2307/41433323

Scarlett, L. (2013). Collaborative Adaptive Management: Challenges and Opportunities. Ecology and Society, 18. https://doi.org/10.5751/ES-05762-180326

Thomann, J., Werner, A., Irvine, D., & Currell, M. (2020). Adaptive management in groundwater management: A review of theory and application. Journal of Hydrology, 586, 124871. https://doi.org/10.1016/j.jhydrol.2020.124871

Barakagira, A., & Ndungo, I. (2023). Watershed management and climate change adaptation mechanisms used by people living in dryland areas of Lokere catchment in Karamoja, Uganda. Environmental & Socio-economic Studies, 11, 45-57. https://doi.org/10.2478/environ-2023-0004

Macleod, C., Scholefield, D., & Haygarth, P. (2007). Integration for sustainable catchment management. The Science of the Total Environment, 373, 591-602. https://doi.org/10.1016/j.scitotenv.2006.12.029

Steiner, F., Simmons, M., Gallagher, M., Ranganathan, J., & Robertson, C. (2013). The ecological imperative for environmental design and planning. Frontiers in Ecology and the Environment, 11, 355-361. https://doi.org/10.1890/130052

Berkes, J., Folke, C., & Colding, J. (2003). Navigating Social-Ecological Systems Building Resilience For Complexity And Change. https://doi.org/10.1017/CBO9780511541957.020

Aleksandar, G., & Milovanov, O. (2017). Brand Strategies in the Era of Sustainability. Interdisciplinary Description of Complex Systems, 15, 78-88. https://doi.org/10.7906/indecs.15.1.6

Rolls, R., Leigh, C., & Sheldon, F. (2012). Mechanistic effects of low-flow hydrology on riverine ecosystems: Ecological principles and consequences of alteration. Freshwater Science, 31, 1163-1186. https://doi.org/10.1899/12-002.1

Gwapedza, D. (2020). The further development, application and evaluation of a sediment yield model (WQSED) for catchment management in African catchments. https://doi.org/10.13140/RG.2.2.11180.39049

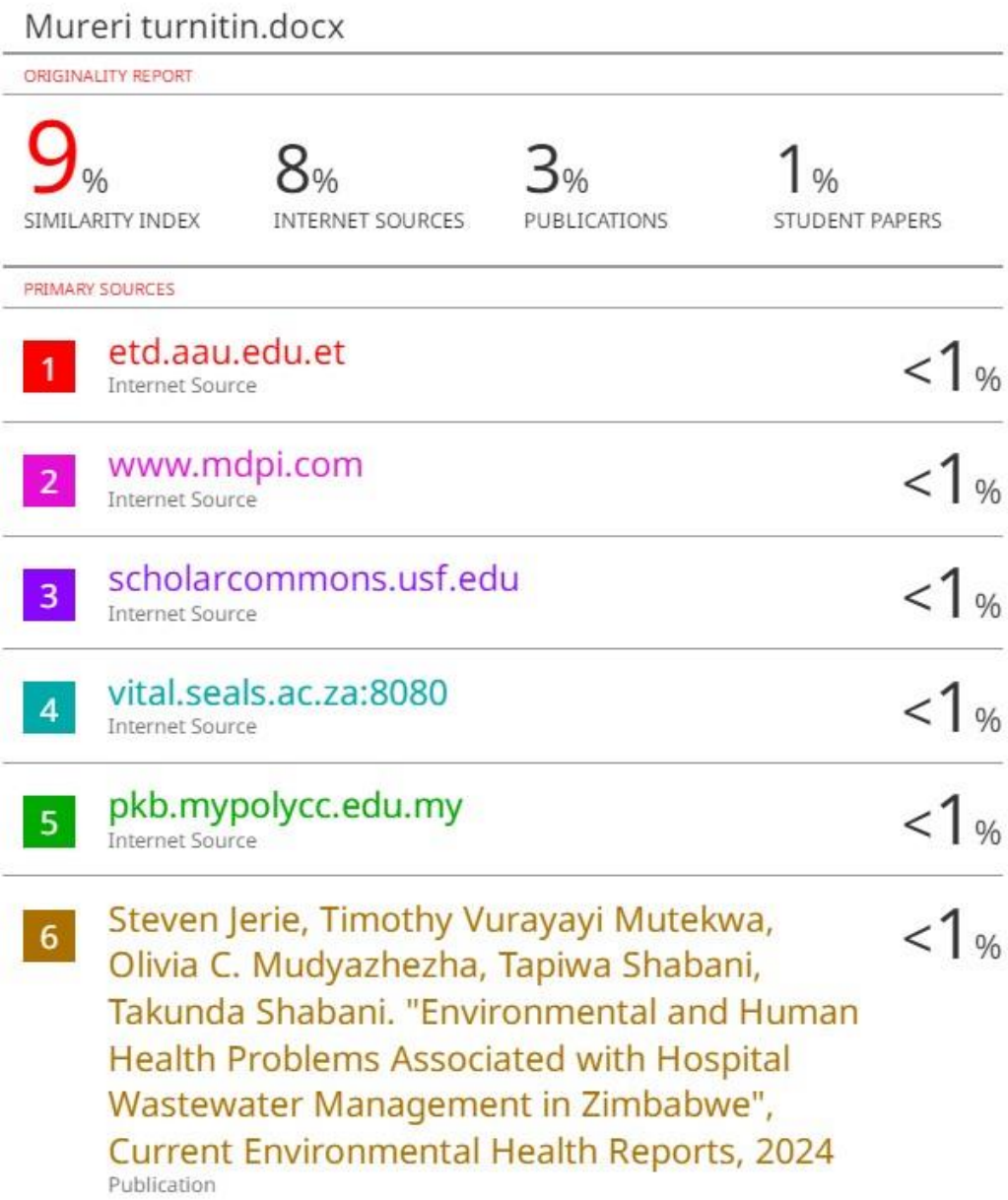
Gumindoga, W., Shekede, M., Mabiza, C., Kupika, O., & Kabo-bah, A. T. (2021). Journal of Environmental Management in Zimbabwe(JEMZ) Vol1(1)(2021).

Coviello, V., Vezza, P., Angeluccetti, I., & Grimaldi, S. (2015). Reducing the impact of soil erosion and reservoir siltation on agricultural production and water availability: the case study of the Laaba catchment (Burkina Faso).\

Mwedzi, T., Tongayi, M., & Bere, T. (2021). Quenching the thirst for Zimbabweans: Anthropogenic activities and their impacts on freshwater ecosystems. Journal of

Environmental Management, 281, 111878. https://doi.org/10.1016/j.jenvman.2020.111878

ZimStat (2022). Zimbabwe 2022 Population Distribution by District Ward Sex and Households. Available on: https://www.zimstat.co.zw/wp-content/uploads/Demography/Census/2022_Population_Distribution_by_District_Ward_SexandHouseholds_23012023.pdf



Mureri turnitin.docx

ORIGINALITY REPORT

9%	8%	3%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	etd.aau.edu.et Internet Source	<1%
2	www.mdpi.com Internet Source	<1%
3	scholarcommons.usf.edu Internet Source	<1%
4	vital.seals.ac.za:8080 Internet Source	<1%
5	pkb.mypolycc.edu.my Internet Source	<1%
6	Steven Jerie, Timothy Vurayayi Mutekwa, Olivia C. Mudyazhezha, Tapiwa Shabani, Takunda Shabani. "Environmental and Human Health Problems Associated with Hospital Wastewater Management in Zimbabwe", Current Environmental Health Reports, 2024 Publication	<1%