RAINWATER HARVESTING PRACTICES AMONG RESIDENTS OF MUTAMA-BWEENGWA OF PEMBA DISTRICT

By

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DECLARATION

I, Muchimba Sinzala, declare that this dissertation represents my original work. It has not previously been submitted for a postgraduate degree or any award at the University of Zambia or any other institution. All works and materials from other sources have been acknowledged and references thereby provided.

January, 2024

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CERTIFICATE OF APPROVAL

This dissertation by MUCHIMBA SINZALA has been approved as fulfilment of the requirements for the award of a Master of Science degree in Geography by the University of Zambia.

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ABSTRACT

Community rainwater harvesting (RWH) systems are seen as an instrument in increasing resilience in recurring droughts and enhancing food security in dry lands of Zambia. Harvested rainwater can be used for agriculture or water supply for households and other domestic uses. This study investigated the practices of rainwater harvesting among residents of Mutama-Bweengwa area in Pemba district, Southern province.

This study used mixed methods approach. A convergent parallel design was used. A total sample of 379 residents were randomly sampled for interviews. 11 key informants were purposively sampled for interviews. The study was done using primary sources, interviews and direct observation. The methods employed in the qualitative data analysis included thematic analysis. Descriptive statistics were used to summarize quantitative data in charts and graphs**.**

The study showed that the residents of Mutama-Bweengwa practice rainwater harvesting using different methods such as dams, buckets, wells, trenches, and soil bunds. However, the study revealed that rainwater harvesting is mainly directly and depended on social, economic and physical factors. Factors that promote rainwater harvesting included technology availability, good environment, good type of roofing, adequate rainfall, good structures and adequate finances. On the other hand, lack of awareness and technical knowledge were key factors that hinder rainwater harvesting. Affordability and accessibility were also identified as potential barriers, emphasizing the importance of considering the financial capabilities and resources of the community in implementing rainwater harvesting systems. The study reviewed that the majority of participants recognized the potential benefits of rainwater harvesting, including improved water security, access to clean water, and enhanced sustainability, etc. However, the study also identified some concerns and challenges that need to be addressed. Therefore, this study recommends for the need for actors of rural development actors such as International Development Agencies, Private Sector, Non-Governmental Organizations as well as Government to provide training and extension services to the residents of Mutama-Bweengwa area so as to develop and disseminate more effective and affordable types of rainwater harvesting and storage technologies as alternatives and to design and develop policy instruments and social institutions that facilitate adoption of Rainwater harvesting and storages practices.

Key words: *Rainwater harvesting, practices, methods and Mutama-Bweengwa.*

DEDICATION

This dissertation is dedicated to my amazing and beloved father, Mr GOLIATH SINZALA. Words can hardly describe my thanks and appreciation to you. You have been my source of support, guidance and inspiration. You have taught me to be determined, unique, believe in myself and to always persevere. I am truly thankful and honoured to have as my father.

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DWA - Department of Water Affairs

GIZ - German Agency for International Cooperation.

NGOs - Non-Governmental organisations

RRH -Rooftop Rainwater Harvesting

SRH - Surface Rainwater Harvesting

RWH - Rainwater Harvesting

WARMA - Water Resources Management Authority

CHAPTER ONE: INTRODUCTION

1.0 Introduction

This section introduces the study. It gives the background to the study, the aim, statement of the problem, objectives and the research questions. Furthermore, the significance of this study and the organisational structure of this dissertation are given in that order.

1.1 Background to the study

The population in the semi-arid lands of the Sub-Saharan African are among the poorest and most vulnerable people. The region suffer from recurring and increased ranges of natural and human-made shocks that act as effective barrier to productive and sustainable livelihoods and demote a majority of the population to a state of chronic poverty Ngingi (2021). Water is our most precious natural resource that most of us have taken for granted. We are now increasingly becoming aware of the importance of water for our survival and its limited supply. The most part of the earth surface, that is about 71% is covered by water and out of the total volume of water available on the surface of the earth, 97% is saline water2% is in form of glaciers and ice and only 1% is fresh and portable water Erickson (2012). Water is essential for all life and is used in many different ways and is also part of the larger ecosystem in which the reproduction of the biodiversity depends. Fresh water scarcity is not limited to the arid climate regions only but in areas with good supply where access of safe water is becoming a critical problem.
The semi-arid lands are characterised by its insufficient water, low productivity especially in agriculture and serious land degradation. This has led to food insecurity, high running costs coupled with high energy demand which has provoked a source for new water resources Malambao and Huang (2016). Water shortages is caused by low water storage capacity, low infiltration, larger inter annual and annual fluctuations of precipitation due to monsoon rains and high evaporation demand Sivanappa (2006). Lack of adequate, quality and quantity of water is a major constraint to development in many areas of the world Lay (2010). It affects every aspect of human life such as health, agricultural yields, food security, technical development, and the economy of states. Water plays a significant role in the lives of people since it is a precious natural resource Nelly (2010).

Globally,, persistent drought, deforestation, poor water infrastructures are among the factors that have contributed to water insecurity WARMA (2019). With the change in climate patterns, people need to be aware of the alarming water shortage that we face currently and the imminent danger of severe shortage in the future Muchanga (2013); Sichingabula (1998). Various methods can be implemented to address the water problem in most areas. Rainwater harvesting is one of the methods that can be used for water conservation. The term harvesting was probably first used by Geddes of University of Sidney. He defined harvesting as the collection and storage of any firm of water either runoff or creek flow for irrigation use harvesting Arunakar (2006). Rainwater harvesting has long been used as a cheap and simple method for meeting water needs with a few exceptions (desalination, deep aquifer extraction), it can be argued that all methods of water supply are in a sense of type of rainwater harvesting. In most cases, rainwater harvesting is seen only necessary in arid or remote places. Nevertheless, rainwater is an available and plentiful resource whose potential is largely untapped *Handia et al (2002*). Definitions of rainwater harvesting vary considerably depending on the source consulted. Some few definitions found in literature are; rainwater harvesting is a technique or strategy for the collection of rainwater and storing it in the right way for future use Malambo and Huang (2016). Rainwater harvesting, in its essence is the collection, conveyance and storage of rainwater Ngingi (2001).Rainwater harvesting is the collection of rainwater for beneficial use Pani (2004. Rainwater harvesting is a method to induce, collect, store and conserves local surface runoff for agriculture in arid and semi-arid regions Boers and Ben-Asher (1982). Rainwater harvesting is the process of concentrating, collecting and storing rainwater for different uses at a later time in the same area where the rains falls or in another area during the same or later time Mbilingi et al (2005). From these definitions, there is no doubt that rainwater harvesting is a physical system that at the least collects, conveys and stores water.

Rainwater harvesting is one of the earliest ways of collecting water for domestic purposes. It is a very traditional way of collecting water from surfaces that do not allow water to soak or penetrate such as rocks outcrops, roofs or corrugated iron sheets and concretes and seasonal rivers by construction of dams. In areas where rain is sufficient, the amount stored could be quite substantial Pani (2004). In India, simple stone-rubble structures for impounding rainwater date back to the third millennium. It was also a common technique throughout the Mediterranean and Middle East. Water collected from roofs and other hard surfaces was stored in underground reservoirs (cisterns) with masonry domes. In Western Europe, the Americas and Australia, rainwater was often the primary water source for drinking water. In all three continents it continues to be an important water source for isolated homesteads and farms Sivanappa (2007); Ngingi (2001). Rainwater harvesting is practiced worldwide.

Approximately 40% of households in South Australia use rainwater to supplement the supply of drinking water, as is done in several regions such as South-East Asia. In Malaysia for example, Erickson (2012), argues that rainwater is also used for commercial purposes including car washing through the placement of plastic collection tanks in places like parking Pani (2004).

In Zambia, the adoption of rainwater harvesting practices has been driven by the need to cope with water scarcity, limited access to safe and reliable water sources, and the unpredictable nature of rainfall patterns. Rainwater harvesting provides an alternative source of water that can supplement other water sources, such as rivers, boreholes, and shallow wells, particularly during dry periods. In recent years, there have been efforts by the Zambian government, non-governmental organizations, and development partners to promote and support rainwater harvesting initiatives GRZ (2022). These initiatives aim to improve water availability, enhance agricultural productivity, alleviate poverty, and enhance resilience to climate change in rural communities Alemaw and Chaoka (2019); Handia et al (2003); Kumwenda and Mwiinga (2019).

Thus, the collection, capturing or diverting of rainwater for various productive usages is widespread especially when it comes to agricultural purposes and soil or water conservation Sibanda (2012). In Mutama-Bweengwa area, GIZ has implemented a rainwater harvesting projects and it is on-going. This project conducts substantial research on methods to augment water availability for various purposes but not so much has been said on the ongoing project and its benefits to the people of Mutama-Bweengwa.

Thus, this study investigated the practices of rainwater harvesting among residents of Mutama-Bweengwa area in Pemba district, Southern province.

1.2 Statement of the problem

There has been little efforts in promoting community based rainwater harvesting projects by government institutions and other development organisation in Mutama-Bweengwa sub-catchment area in spite of the water challenges that the area experiences especially in the dry season and during droughts periods. Water insecurity in Mutama- Bweengwa area is persistent and has adverse effects on livelihood activities for local people. The insecurity of water in this area poses a serious danger to food security and the well-being of residents as most of their livelihoods largely depend on water. Like many other rural areas, Mutama-Bweengwa cannot satisfy its domestic water needs and only 30% of the total population had access to water improved sources Tena (2021). One major environmental problem Mutama Bweengwa area is currently facing is water scarcity and it is said to be one of the rural areas in Zambia that will experience water scarcity or stress by 2025 UNDP (2018). The area is already facing water supply shortages, this problem is worsened with the inadequate amount of rainfall the area receives Muchanga (2020).

Mutama-Bweengwa exceeded the rate at which the available water supplies are replenished and this is because the population growth has been rapid due to a number of factors such as polygamy and early marriages. It has a total population of 101,021 and the issue of having sufficient water in the water sources for its population and the ability to properly distribute this water has been a challenge. 90% of the population in Mutama-Bweengwa is poor and cannot afford most of their basic needs and with the above stated problems, water has become so scarce and expensive. There are significant household water supply challenges including quantity and quality, which have economic and social implications Malambo and Huang (2016). This problem is worsened by low level exploitation of opportunities for rainwater harvesting Lay (2010). The significance of the practices of the community participants has been ignored mainly by excluding them from the designing, implementation and assessment stages of the rainwater harvesting projects for enhancing food security and other livelihood activities. This has led to problems relating to failed adoption processes due to insufficient participation by the resident farmers targeted by the rainwater harvesting projects. Therefore, adoption of various water harvesting techniques needs to be evaluated so as to determine the success of the project goals. This is because climate change and variability are expected to continue affecting water availability (Muchanga, 2013; Sichingabula, 1998).

It is commonly said that water is everywhere, however, portable water is not accessible by everyone Malesu et al (2005). In Mutama-Bweengwa area, thousands of people lack access to clean water for domestic and other purposes. In order to fight this problem, sustainable water management is a must. Therefore, this study investigated the practices of rainwater harvesting among residents of Mutama-Bweengwa area in Pemba district, Southern province. The district in southern province receives inadequate, erratic and unreliable rainfall, which implies that water harvesting and storage technologies would be vital to ensuring water availability during dry periods and to make water available to every individual resident in the area WARMA (2019).

1.3. Aim of the study

To investigate the rainwater harvesting practices among the residents of Mutama-Bweengwa of Pemba District.

1.4 Research objectives

i) To examine rainwater harvesting practices among the residents of Mutama-Bweengwa.
ii) To find out the factors influencing the rainwater harvesting practices in Mutama-Bweengwa area.
iii) To analyse the pros and cons of rainwater harvesting technologies in Mutama-Bweengwa area.

1.5 Research questions

i) What methods of rainwater harvesting are being in the study area?
ii) Which methods rainwater harvesting would you recommend in your area?
iii) What are the factors promoting rainwater harvesting?
iv) What are the factors hindering rainwater harvesting?
v) What are the pros of rainwater harvesting system?
vi) What are the cons of rainwater harvesting system?

1.6 Significance of the study

The need to conduct this research arose from the fact that Mutama-Bweengwa sub-catchment falls in the agro-ecological region which is hard hit with climate change and this has impacts on the livelihood of people due to water shortages. The recurrent droughts in Pemba district where the catchment is located negatively impacts water resources, forests and agriculture which are major source of livelihood for people UNDP (2018). The information which will come from this study could enable various actors of rural development such as NGOs, Government and International Development Agencies to come up with appropriate measures and policies on rainwater harvesting as well as addressing the impacts of climate change in Zambia. The findings of this this study might help NGOs to come up with sustainable rainwater harvesting methods and asset creation projects as a way of addressing water scarcity problems in Zambia. In so doing, people will be able to withstand climate change impacts not only in Mutama-Bweengwa area but in other areas which are affected by climate change

This study would be cardinal to the government as it may help them to formulate efficient and coordinated policies that may help improve and strengthen rainwater harvesting policies and adoption in order to increase resilience of people to impacts of climate change. The findings from this study could help International Agencies to know to know how helpful rainwater harvesting is as well as the severity of climate change impact on local livelihood. Once this is known, it may be easier to make decisions of whether or not to increase and expand rainwater harvesting practices and projects so as to help people combat impacts of climate change.

Further, the study may make known how the resource user perceive rainwater harvesting which is very important as it will bring insights for practitioners, government, civil societies, policy makers, planners and other agencies to consider with regard to rural areas. Additionally, information from this study might also be used as literature review and compliment studies which have been conducted already.

1.7 Organisation of the paper

This dissertation is divided into seven chapters. Chapter one has provided the background knowledge on the issues of rainwater harvesting, problem. It also outlines the statement of the problem, aim, objectives, research questions, research hypotheses and the significance of the study. Chapter two reviews existing literature by first showing the theoretical framework and research gap. Thereafter, a review of the perceptions, attitudes and practices towards rainwater harvesting. Chapter three describes the study area in terms of its physical location, climatic characteristics as well as its socio-economic status. Chapter four illustrates the methodology that were employed in this study, specifying the design, targeted population, sampling and data collection techniques and data analysis methods espoused by the study. It also contains the philosophical assumptions of the study. The fifth chapter presents the findings of the study which are discussed in the sixth chapter. The seventh chapter concludes the study and provides the recommendations of the study based on the findings.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This section presents a review of the literature consulted. It presents some of the arguments and findings by other scholars on rainwater harvesting.

2.1 Theoretical Framework

This study employed the Social Ecological Systems (SES) framework. The SES framework examines the interactions between social and ecological systems, recognizing that human actions and behaviours are influenced by both social and environmental factors Leslie *et al* (2015); Nagel and Partelow (2022). In the context of this study, this framework allowed the researcher to explore how rainwater practices of residents regarding rainwater harvesting are shaped by various social, cultural, economic, and environmental factors. By using the SES framework, this study analysed the perceptions of residents at multiple levels. This included their individual beliefs, attitudes, and knowledge about rainwater harvesting, as well as the broader social and cultural norms that could have influenced these beliefs. Additionally, the study examined the ecological factors that could have affected the viability and acceptance of rainwater harvesting, such as the availability of rainfall, water quality, and access to infrastructure. Furthermore, the SES framework helped the researcher to understand the dynamics and interactions between different stakeholders involved in rainwater harvesting. This included exploring the role of community leaders, government agencies, NGOs, and local institutions in shaping perceptions and promoting the adoption of rainwater harvesting practices. Overall, the Social Ecological Systems framework provided a holistic and comprehensive approach to understanding the perceptions of rainwater harvesting among the residents of Mutama-Bweengwa community Leslie *et al* (2015); Nagel and Partelow (2022).

2.2. Rainwater harvesting

According to Boers and Ben-Asher (1982), rainwater harvesting is a technique to induce, collect, store and conserve local surface runoff for agricultural purposes such as gardening, irrigation, etc. Roofs act as efficient catchment systems where rainwater is collected or harvested for domestic use (Boers and Ben_Asher, 1982). Rainwater is harvested by building simple rainwater catchment systems where schools, houses and municipal buildings can harvest rainwater from their roofs and gutters to store for drinking as well as for use in times of emergency and to supplement unreliable water sources Thomas and Martinson (2007). Biazin *et al* (2011) identified the most common micro-catchment (*in situ*) strategies used as: pitting, contouring, terracing, and micro-basins. The macro-catchment *(ex situ*) strategies widely used across sub-Saharan Africa include; traditional open ponds, cisterns, earthen dams, sand dams, and ephemeral stream diversion Biazin *et al (*2011).

Rainwater harvesting is the method by which rainwater that falls upon a roof surface is collected and routed to a storage facility for later use. Rainwater harvesting (RWH) systems are a compilation of many components and processes, including (but not limited to) a catchment surface, conveyance system, pre-storage filtration, storage container, pump, post-storage filtration/treatment and post-storage distribution system. Rainwater harvesting (RWH) is far from a novel practice, as its use has been documented in ancient Greek and Roman civilizations Crasta *et al (*1982). Traditionally implemented in regions with limited access to water resources, RWH was commonplace in India, Jordan and other parts of Asia, Italy, South America and portions of Africa from the middle Ages through the late 1900s. The 20th and 21st centuries has brought population growth, climate change and increasing water supply shortages to many areas, including Australia, Germany, China and the United States, RWH systems have grown in popularity and quantity in recent years as an alternative water supply in these regions Mendez *et al* (2011).

2.3 Global Perception and practice of Rainwater Harvesting

The global demand for fresh water has multiplied by six in the last century, growing steadily by approximately 1% per year since the 1980s Stanford (2010). In addition, it is estimated that by 2050, the global water demand will increase by between 20% and 33% Ngingi (2021). In many parts of the continent, groundwater extraction is currently exceeding its recharge capacity, thereby progressively depleting water resources and deteriorating its quality Syed (2017).Thus, as water scarcity becomes worse, the growing competition between the different productive sectors for this limited resource becomes more evident. As a result, many regions around the globe continues to face conditions of constant or seasonal water scarcity as a result of increased demand in agriculture and other productive sectors and the uncertain availability of water resources induced by climate change Pani (2004). Thus, globally, rainwater harvesting systems are perceived to a feasible alternative to increase water resources for agricultural use, domestic and other uses. However, the installation of these systems in communities where there’s scarce water resources is very limited Wanjoni (2013) Therefore, it is necessary to further investigate the resident's opinions and attitudes towards these systems in order to develop specific measures that respond to their needs. Global Practices of rainwater harvesting have been discussed further bellow according to continents.

2.3.1 Rainwater Harvesting in Asia

Water has been harvested in India since antiquity. Evidence of this tradition can be found in archaeological remains. The decentralized, large-scale, check dams constructed in Gujarat State of India is an excellent example of RWH movement. Previously, Gujarat overcame many obstacles of water-deficient state by pursuing constant innovation in RWH. Rainwater harvesting system has been perceived as an alternative to the water scarcity in many parts of India. In many parts of the country, particularly in rural areas, traditional methods like building step wells (baoris) and storing rainwater in underground tanks (tanka) are still in use. In recent years, there has been a renewed focus on rainwater harvesting due to water scarcity issues in urban areas as well. Today, Gujarat is considered a role model for sustainable development across the India. This can be attribute to the sagacious work undertaken by the State Government with NGOs and people participation in the field of RWH Rainwater harvesting has been practiced in India for centuries Pani (2004).

In Indonesia, groundwater is depleting in urban areas due to reduced water infiltration. The decrease in groundwater recharge in the cities is directly proportional to the increase in the pavement and roof area. High population density opened another dimension to the aforementioned problem Xiaoyan (2002). Keeping the problem into view, the Indonesian government passed a regulation that all buildings must have an infiltration well which applies to two-thirds of the territory, including the Special Province of Yogyakarta, the Capital Special Province of Jakarta, West Java and Central Java Province. This regulation reduced the water deficit from 53 to 37% and increased net savings of 16% in Java and Madura.

In Bangladesh, rainwater collection is a viable option to provide safe drinking water to arsenic affected areas. About 1000 RWH systems have been installed in the rural areas of the country, by the NGO Forum for Drinking Water Supply & Sanitation. The rainwater that is harvested is used for drinking and cooking and its acceptance as a safe, easy-to-use source of water is increasing amongst local users. Water-quality testing showed that water can be preserved for 4 to 5 months without bacterial contamination Pani (2004).

Rainwater harvesting has been practiced in China for thousands of years, primarily in rural agricultural regions. Traditional methods involve collecting rainwater in ponds, cisterns, and underground storage systems. For instance, RWH is highly practiced in Gansu, one of the driest provinces in China which receive an annual precipitation of about 300 mm and have a potential evaporative demand of 1500–2000 mm. This province faces acute water scarcity and the people rely mostly on rain fed agriculture due to scarce surface and groundwater. As such, RWH has become an important option for Gansu Province to supply drinking water, develop rain-fed agriculture and improve the ecosystem in dry areas. In modern times, China has also implemented large-scale rainwater harvesting projects in urban areas to enhance water conservation and reduce flooding Pani (2004).

2.3.2 Rainwater Harvesting in North America

Rainwater harvesting is practiced in various parts of the United States, especially in regions prone to droughts such as the south-western states. Many households and businesses use rain barrels, cisterns, and rooftop collection systems to capture rainwater for irrigation and other non-potable uses Anschutz (2003).

Rainwater harvesting in Mexico dates back to the times of ancient civilizations like the Mayans and Aztecs. Traditional techniques such as rainwater ponds (aguadas) and underground cisterns (aljibes) are still being used in rural areas. Mexico has also implemented modern rainwater harvesting systems in urban areas to alleviate water scarcity issues Hurtang (2002)

2.3.3 Rainwater Harvesting in Europe

Rainwater harvesting is popular in Germany, especially for residential and commercial buildings. Many households have rainwater collection systems installed to meet non-potable. Rainwater harvesting is mainly used for gardening, toilet flushing, and laundry. Germany has also implemented rainwater harvesting on a larger scale for storm water management and groundwater replenishment Murgor (2013)

Spain has a long history of rainwater harvesting, particularly in its arid regions. Traditional techniques like building cisterns (aljibes) and underground storage tanks (aljibones) have been used for centuries. Recently, Spain has promoted rainwater harvesting as a sustainable water management strategy, especially in urban areas Stanford (2010)

2.3.4 Rainwater Harvesting in South America

In the North-eastern part of Brazil, annual rainfall ranges between 200 to 1000 mm, with an uneven regional and seasonal rainfall pattern. In this region, rainwater is collected in hand-dug rock catchments and river bedrock catchments. About one million rainwater tanks were constructed and increased the assurance of rural water supply over a 5-year period and thereby satisfying drinking water demands of 5 million people. The results of a study performed by wanjohi (2013) showed that the potential water saving by using water harvesting in 62 cities in Brazil ranges from 34 to 92%, with an average potential for potable water saving of 69%.

2.3.4 Rainwater Harvesting in Africa.

Rainwater collection is common in Africa with projects currently in Botswana, Togo, Mali, Malawi, South Africa, Namibia, Zimbabwe, Mozambique, Sierra Leone, and Tanzania among others. Since 1970s, many projects emerged in different parts of Kenya, each with their own designs and implementation strategies. These projects, in combination with the efforts of local builders called "fundis" operating privately and using their own indigenous designs, have been responsible for the construction of many tens of thousands of rainwater tanks throughout the country Ngingi (2001). In African dry lands, soil and water conservation practices, such as RWH strategies stabilized agricultural landscapes in semiarid regions and to make them more productive and more resilient toward climate change. Among the most common soil and water conservation techniques, RWH is massively promoted by NGOs, national agricultural extension services and government agencies in African countries, thus, RWH practices already have a long tradition Sivaappa (2007). Despite the effectiveness of some water conservation techniques, adoption by farmers has been poor mainly because of several factors among them; high labour intensity. For instance, in Tanzania, the cost of making tie ridges is estimated at 33% higher than conventional land preparation using hand hoes Ngingi (2001).

The rapid expansion of rainwater-harvesting systems has increased in recent years in some parts of Africa Syed (2017). In Kenya, rainwater-catchment systems are being considered as a viable and important water-supply option such that most of the farmers are aware about water harvesting techniques and willing to adopt them (Ibrahim, 2012). Rainwater is also harvested to mitigate the water crises in various other parts of Africa such as Botswana, Togo, Mali, Malawi, South Africa, Namibia, Zimbabwe, Mozambique, Sierra Leone, and Tanzania Syed (2017).

According to the Minagri (2007), despite Rwanda being known as an equatorial country with high rainfall, poor water management, low soil fertility, unreliable and erratic rainfall have continued to threaten food production in major arid and semi-arid regions of the country. As such, in 2007, the government of Rwanda and non-governmental organizations introduced a national food security strategy based on the promotion and implementation of small scale irrigation. The initiative involved the introduction of RWH technologies at household level as an alternative intervention to mitigate the effects of the erratic nature of rainfall in the arid and semi-arid parts of Rwanda for achieving the Millennium Development Goals of reducing underdevelopment and poverty by achieving economic growth Minagri (2007).

Rainwater harvesting can reduce over dependence on centralized piped water supply and the undesirable effects of climate change. Rainwater harvesting awareness alone may not be good enough if water problems through rainwater harvesting are to be solved. A study by Ishaku *et al* (2013) in some selected villages of Sahel Savannah Ecological Zone in Borno State Northeastern Nigeria revealed that despite the area having over 80% awareness of rainwater harvesting practices only 2% of households harvest rainwater due to the seasonality of rain-fall coupled with inadequate water storage facilities. They, therefore, argued that there was need to embark on massive rainwater harvesting with corresponding water reservoir as a way to reduce the effects of the five months' dry spell which had been experienced in the region Ishaku e*t al* (2013). According to the UNEP and World Agroforestry Center (2005) rain water harvesting is not new. There is evidence of its existence about 4000 years ago in Palestine and Greece. In ancient Rome, residences were built with individual cisterns and paved courtyards to capture rainwater to augment water from city's aqueducts. As early as the third millennium BC, farming communities in Baluchistan and Kutch impounded rain water and used it for irrigation. In Tunisia, jessours have been used for centuries to collect run-off from long hill slopes. Farmers build earthen dams across the valley floors to trap the run-off water and silt. In the desert areas of Arizona and northwest New Mexico, floodwater farming has been practiced for at least 1000 years. In the "Khadin" system of India and the spate irrigation system of the Great Horn of Africa, floodwater is impounded behind earth bunds, and crops then planted into the residual moisture when the water infiltrates. Kenya's water policy takes into account all the relevant issues including water conservation and preservation of its quality. In this regard, mainstreaming of rainwater harvesting is very prominent. In agricultural production; rainwater harvesting is mainstreamed into the soil and water conservation. This approach promotes rainwater harvesting on the field thus minimizing run off.

2.4 The state of rainwater harvesting in Zambia

Documentation on rainwater harvesting in Zambia has been seldom available, and when found, it is reserved to agricultural applications where non-governmental organisations (NGOs) drive rainwater harvest (RWH) development for rural use. These activities were generally not coordinated systematically in the past due to lack of a Rainwater Harvesting Association Kasuba and Muzyamba (2009). As a result, rainwater has been ignored and under-utilized as a resource in the rural area with very few RWH systems installed in schools using the simplest of methods Handia *et al* (2003).

The government has, in the 8th National Development Plan, recognized the importance of rainwater harvesting and integrated it into national policies and strategies. This recognition has led to the development of programs and projects that provide technical support, capacity building, and financial assistance to communities interested in implementing rainwater harvesting systems GRZ (2022). Furthermore, partnerships with international organizations and donors, such as the United Nations Development Programme (UNDP), the European Union, World Vision Zambia, and the German government through GIZ, have facilitated the implementation of rainwater harvesting projects in Zambia. These initiatives focus on promoting sustainable and innovative rainwater harvesting techniques, raising awareness, and building the capacity of local communities to adopt and maintain rainwater harvesting systems in rural areas Alemaw and Chaoka (2019; Handia et al (2003); Kumwenda and Mwiinga (2019); Muleba (2018). For these programmes to be implemented successfully, there is need for people in the community to understand the advanced methods and techniques in rainwater harvesting. Currently, there is limited knowledge on this subject. A research by Huang and Malambo (2016) investigated the level of knowledge on RWH among the residents of Lusaka and the results showed that only 8.33% had a positive "good" idea while a slightly larger 16.67% elected to have "moderate" knowledge of the practice of RWH. Comparatively, lack of knowledge was shown when 33.33% had no idea what RWH and 41.67% had a very low understanding of RWH. For most rural areas, rainwater harvesting is unheard of. Therefore, this study is one of the few studies undertaken focusing on rainwater harvesting in a rural community.

2.5 Methods and Techniques of harvesting rainwater

There are mainly two methods of rainwater harvesting, namely: surface runoff harvesting and rooftop rainwater harvesting.

2.5.1 Surface Rainwater Harvesting (SRH)

This is a system where the rainwater flowing along the ground during the rains will be collected to designated water storage. It involves capturing rainwater from paved surfaces and other open areas and directing it to storage tanks or other storage systems for later use. It is suitable in urban areas where large surface areas are paved, tarred and bare and runoff after rains is increased. In case of rural areas where there are rivers and streams, the flow of small tributaries of rivers or reservoirs is redirected to store the surface runoff. The surface runoff is stored in ponds, tanks, and reservoirs built for this purpose. During the storage of rainwater, efficient and effective water conservation methods (reducing evaporation) are incorporated to sustain healthy and hygienic water. The main components of the SRH include the catchment area (this refers to the surface area from which rainwater is collected such as drive ways, parking lots, or any other paved or no-paved surfaces), gutters and downspouts to channel rainwater from the catchment areas to the storage area, filters to remove debris, leaves and other contaminants from the collected rainwater before it enters the storage system, storage tank and the distribution system Mwamila *et al* (2016); Syed (2017).

2.5.2 Rooftop Rainwater Harvesting (RRH)

As the name suggest, a rooftop rainwater harvesting system is a specific type of surface rainwater harvesting system that focusses on capturing rainwater from the rooftops for various uses. It involves collecting rainwater that falls on the rooftop surface, directing it through a series of components and storing it for later use. Rainfall falls onto the roof, is collected by gutters, and is transported to the storage container by a network of pipes for most of the systems. Filtration prior to storage is frequently used to keep trash, leaves, and silt out of the storage container. The water is then transported to the storage container via a network of pipes. For the purpose of preserving the quality of water collected for later use, an initial flush diverter may be added to the conveyance piping to redirect the dirtiest runoff water (typically the first 1 to 3 mm) away from the storage container Kus *et al* (2010). The water is either pumped or gravity-drained from the storage container to the point(s) of use.

The components are the same as for the SRH except that the gutters are installed at the edges of rooftops and downspout are connected to the gutters. This Method can be adopted at individual homes or schools where the rainwater is captured from the roof catchments of domestic houses or commercial buildings, diverts, and stored in the tanks through gutters. The harvested rainwater can either be stored in a tank or diverted to an artificial recharge system to meet daily needs such as flushing toilets, washing machines, washing vehicles, gardening, showers, sinks, and baths. The rooftop rainwater harvesting system consists of sub-components such as catchments, transportation, first flush, and filter Syed (2017).

Rooftop Rainwater Harvesting, according to Kagabika and Kankuyu's study in Niboye in Kicukiro, Kigali, helps reduce surface runoff. For example, a 5-cubic-meter tank can retain up to 60 percent of the water that falls on the roof. In this regard, the same study highlights that, on a larger scale, the impact can be greater in high-density areas and when the majority of residents embrace the practice Kagabika and Kankuyu (2021).

2.6 Factors Influencing Rainwater Harvesting Practices

The process of rainwater harvesting involves the collection and the storage of rainwater with the help of artificially designed systems that run off naturally or man-made catchments areas like compounds, rock surface, hill slopes and rooftops, several factors play a vital role in the amount of water harvested. Some of these factors are as follows

2.6.1 Ecological Factors and their influence on adoption of rain water

Goyal (2005), a sufficient, clean drinking water supply is essential to life but millions of people throughout the world do not have access to this basic necessity. Even after the intensive efforts of engineers, planners, builders, governmental and Non-Governmental Organizations (NGOs) to bring potable water to the poorer people of the world, the situation is still dire. This is because of cost, climate, technology, and hydrology, social and political reasons. Goyal (2005) further reported that the sustainability of the watershed project depends on the ecological and technical parameters like construction of water harvesting structures, soil and water conservation measures. Similarly, the economic parameters are like the benefits to the masses in comparison to the cost in terms of water and irrigation security, food security, fodder security and ensured employment through agriculture. But the major contribution is from people's participation or social sustainability of the project. If peoples' participation is achieved it can lead to better implementation of the project, growth of the project and maintenance of the created infrastructures on sustainable basis. This study will focus at the following ecological aspects namely water sources and water supply, soils and water harvesting catchments and storage structures.

2.6.2 Rainfall and water supply

According to Erickson (2012), among the eco-climatic conditions, rainfall quantity and pattern are the most important factors. Rainfall quantity is the most unpredictable variable in the calculation. Hence reliable rainfall data for a period of at least ten years is considered to calculate the potential rainfall supply for a given catchment. The rainfall data from the nearest stations with comparable conditions are preferably considered. Rainfall pattern or the number of annual rainy days influences the need and design for rainwater harvesting. The need for the collection of rainwater in a region is more if the dry period is long or the annual rainy days are fewer. Big storage tanks would be needed to store rainwater if the dry period is too long. In such regions using rainwater to recharge groundwater aquifers is a better alternative than storing it.

According to Xiaoyan and Ruiling (2002), Water is the major limiting factor for farming, forestry and animal husbandry and it is the key factor for environmental improvement. Limited and erratic precipitation often results in crop failure as well as serious soil and water loss but rainfall harvesting can change the distribution pattern of rainfall runoff in time and space, which would supply humankind with steady water sources to some extent. Rainwater harvesting would provide the possibilities of setting up new agricultural ecological system and whereby improve ecological environments. However, Hartung (2002), stated that water is life. Yet millions of people throughout the world lack enough of this basic commodity for their hygiene and/or have no good quality water for drinking and preparing food. In many families both women and men also need water for animals, vegetables, crops and trees. Where groundwater and surface water sources are in short supply, rainwater may be a sustainable alternative or supplement.

Sharda and Ojasvi (2005), the gap between water supply and demands necessitates harnessing of available water resources with efficient water conservation and management techniques. It has been amply demonstrated that participatory water resource development in watershed management programmes has significantly increased food grain and biomass production and resulted in moderation of floods, mitigation of droughts, augmentation of water ground recharge, employment generation and improvement of socio-economic conditions of the local people. The water harvesting practices include in-situ water conservation, micro-catchments, and ex-situ water harvesting and storage systems. Rainwater harvesting technologies are highly location specific and practices evolved in a given agro-ecological region have limited applicability in other regions. Of the various factors affecting water harvesting technology, rainfall is most important parameter due to its erratic temporal and spatial variations. The water harvesting practices in various parts of the country can, therefore, be best described based on agro-ecological regions which are having homogeneity in bio-physical attributes of soil, climate, topography and land uses.

2.6.3 Soils and water harvesting

According to Sivanappa (2007), water is essential for all life and is used for food production, drinking and domestic uses and industrial use. It is also part of the larger ecosystem on which bio diversity depends. Precipitation, converted to soil and groundwater and thus accessible to vegetation and people, is the dominant pre-condition for biomass production and social development in dry lands. The amount of available water is equivalent to the water moving through the landscape.

It also fluctuates between the wet and dry periods. Fresh water scarcity is not limited to the arid climatic regions only since even in areas with good supply, the access to safe water is becoming a critical problem. Lack of water is caused by low water storage capacity, low infiltration capacity, large inter-annual and annual fluctuations of precipitation and high evaporative demand. During good rainy years, excess rainwater should be stored in the soil and also underground using suitable soil moisture conservation measures and water harvesting structures on a watershed basis. This stored water can subsequently be used for irrigation.
According to Anschutz (2003), the type of the soil depends on the structure (how sticky is the soil) and texture (size of the soil particles) of the soil. There are three types of the soil depending on soil texture namely sand, clay and loam soil. Water infiltration is higher on sandy soils. Water retention is high on the loam soil followed by the clay soil which has the highest retention rate.

2.6.4 Social Economic factors and their influence on adoption of rain water harvesting

Goyal (2005),reported that economic parameters are like the benefits to the masses in comparison to the cost in terms of water and irrigation security, food security, fodder security and ensured employment through agriculture. But the major contribution is from people's participation or social sustainability of the project. If peoples' participation is achieved it can lead to better implementation of the project, growth of the project and maintenance of the created infrastructures on sustainable basis. According Sinavappa (2007), the socio-economic factors influencing farmers' decisions to adopt rain water harvesting techniques were categorized in household variables (gender, education and age) and economic variables (wealth status, access to credit, social status and household members' perception). All the factors have different effects on the adoption rate of the rain water harvesting techniques. The important role of financial, human and land resources endowment of a household is very vital in the decision of the household on whether to adopt any newly introduced agricultural techniques.

Sinavappa (2007) further observed that rich farmers are most enthusiastic in adopting rain water harvesting technology than poor farmers. In addition most the rich household invest in the costly concrete lined ponds and concert lined circular ponds. This is because the financial bequest of the rich and middle income households motivates them to take credit and invest in the Rain water harvesting technology. However, the poor households preferred either not to adopt the Rain water harvesting techniques or adopt the less expensive ones.

Pani (2004) reported that water harvesting improves agriculture, forest covers, animal husbandry and the ecology. It also resolves many social issues and enhances the people's capacities to assess the situation and examine possibilities for addressing drought more constructively and organize themselves into groups to tackle the problem collectively. It will put a check on protests, demonstrations, road-blockades, riots of city dwellers against farmers, villages against towns, towns against cities, citizens against the government, and people against people.

2.6.5 Capital

According to Wanjohi (2013), most countries were hopeful that opportunities provided by strengthened democratic governance, and improving economies will accelerate progress. However, poverty levels still remain high. According to Murgor (2013), one of the potential limitations to farmers in adopting modern technologies and inputs is the financial related problems such as cost of hired labour is too high, transportation cost is high for agricultural products, cost of construction material is high and lack of credit access or shortage of capital. It is difficult to increase agricultural sector productivity without efficient credit facility, given the fact that the majority of farmers are resource-poor.

According to Stanford (2010), the capital cost of rainwater harvesting systems is highly dependent on the type of catchment, conveyance and storage tank materials used. Compared to deep and shallow tube wells, rainwater collection systems are more cost effective, especially if the initial investment does not include the cost of roofing materials. However, Hurtang (2002), reported that the associated cost of rain water harvesting system are for installation, operation and maintenance. Of the costs installation, the storage tanks represent the largest investment which can vary between 30 and 45% of the total cost of the system dependent on a system size. A pump, a pressure controller and fittings in addition to plumber’s labor represent other major costs of the investment.

2.6.6 Labour

According to Anschutz (2003), the major cost of water harvesting scheme are in the earth and stone work. The quantity of digging of drains, collection and transport of stones, maintenance of the structures will provide an indication of the costs of the scheme. Usually these labour requirements are high. Most water harvesting structures are dug in the dry season and farmers are engaged in other activities like cattle herding or wage labour on plantations or in urban areas. Labour requirements depend very much on power sources available. The choice of the equipment depends on power sources available. In small scale systems labour is mostly carried out using hand tools. Drought animals like oxen, donkeys and horses can be used for ridging and bed making. Simple ridging equipment exist which may be drawn by animals for instance mould board ridges. According to Erickson (2012), despite the effectiveness of some water conservation techniques, adoption by farmers has been poor mainly because of several factors among them high labour intensity. To address these challenges, there is a need of a more efficient capture and use of the scarce water resources in arid and semi-arid areas. An optimization of the rainfall management, through water harvesting in sustainable and integrated production systems can result in improved livelihood of the small-scale farmers' through improved rain fed agriculture production.

2.6.7 Training and extension service providers

According Erickson (2012), the problem is that farmers and communities do not have the knowledge or the means to implement suitable techniques in the appropriate way. In addition it is necessary that some be tested under current conditions. The capacity of the communities and the national research program and extension services needs enhancement in the area of water harvesting. Conditions are now suitable for mobilizing human and financial resources for improving the situation under appropriate physical and socioeconomic environments. Success achieved in water harvesting implementation in similar areas encourages adoption of these approaches at large scale in this area. According to Kariuki (2003), the promotion of rain water harvesting technologies is done through Government ministries, communities, individuals, development partners, institutions of research and higher learning, NGOs and private companies.

2.7 Importance of rainwater harvesting

Rainwater harvesting is increasingly viewed as a practical means of reducing storm water runoff and supplementing water supply in water-scarce regions, although its widespread adoption has been limited in urban areas Dallman *et al* (2016). The growth of urban communities has created significant challenges for water management. Increased paved and impervious surfaces in urban areas disrupt the natural processes of infiltration of rainwater, consequently increasing runoff volume and impairing water quality in local waterways. This situation compromises public safety through increased flooding, and adversely impacts on the ecology, geomorphology, and socioeconomic benefits of the receiving waters (National Research Council, 2008). Walsh *et al* (2014) observed that public attention is increasingly turning towards the potential value of rain where capturing and reusing rainwater is regarded as a potentially viable strategy both for supplementing local water supply and for reducing pollution from storm water runoff Walsh *et al* (2014). This is because by using captured rainwater, urban residents can avoid unnecessary use of potable water for non-portable uses, such as landscape irrigation, while also reducing the volume of storm-water runoff carrying pollution to rivers, lakes, and beaches Hanak and Davis (2006). Reduced demand for portable water will also mean saving energy and associated carbon emission reductions. These two resources are closely linked, as water is required to produce energy and energy is required to transport, treat and distribute water Ruberto *et al* (2013). Furthermore, according to Munyareza *et al* (2016), rainwater harvesting (RWH) technology is increasingly adopted as a strategic pathway for reducing poverty in rural drought prone areas for enhancing agricultural productivity and boosting farm income Munyareza *et al* (2016).

A study conducted by munyareza and others in Natarama sector in Rwanda showed that 42.5% of households have adopted RWH ponds. They also observed that the adoption level of RWH ponds was low due to the lack of training about the role and use of RWH ponds before their implementation. Apart from this, the study revealed the low level of public involvement during the site selection for ponds associated with social conflicts among water users. However, the study further revealed that the use of RWH ponds positively impacts on agricultural income on 1/4 hectare per year by about 3100 United States Dollars. On the other hand, the study revealed some negative impacts. The RWH technology can cause dangerous effects such as social conflicts, breeding site for mosquitoes, water related diseases, accidents and others with a level of severity of 32%, 24%, 20%, 16% and 8%, respectively. This happens mostly when the RWH ponds are not properly managed Munyareza *et al* (2016).

Rainwater harvesting has many benefits. It is a sustainable water management practice that can be implemented by anyone on many different levels, from a simple rain barrel to a comprehensive rainwater harvesting system that integrates with an irrigation system or household plumbing Consult (2011); Handia *et al* (2003). Rainwater harvesting has been identified to have many potential benefits in both urban and rural communities. These include securing and increasing crop production in semi-arid regions where rainfall is insufficient, control of soil erosion and land degradation Nelly (2010). Rainwater harvest can help alleviate demands on public water supply systems and promote better practices in the public Consult (2011); Lay, (2010). It can also be argued that a measure of value of rainwater could be the money saved by consumers for reduced use of municipal water, based on rates charged by various water agencies. Droughts are common in the southern part of Zambia, where this study is located. This area and some other parts in the country have had disastrous experiences for livestock and crops. By collecting and storing water during the rainy season, rainwater harvesting will enable the residents to use it later on in dry seasons. This would ensure they have water for farming and other necessities while lessening the effects of droughts. Water scarcity has the potential to impede a society's desired social and economic advancement.

According to Muleba (2018), Zambia Water Forum Exhibition chairperson professor Imasiku Nyambe observed that water harvesting in Zambia has not been fully exploited. Water harvesting is critical in mitigating the effects of climate change. With prudent management of rainwater, Zambia's food security could be enhanced at both household and national level as harvested water could be used in the dry season for irrigating crops at household and commercial level. Professor Nyambe pointed out that dams should be constructed that could be used to store rainwater which can later be used for other purposes during the dry spell. Dams are important for the communities as the impounded water is used for various purposes including flood control, domestic supply, crops, animal watering and recreation Chomba and Sichingabula,

(2016); Muchanga (2020); Muleba (2018). Furthermore, the Zambia Rainwater Harvesting Association (ZRHA) observed that there is great potential of rainwater harvesting in Zambia in all regions. The potential is in flood control and drought control on one part, and water conservation on the other part Sibanda (2012).

Rainwater harvesting reduces flooding as the excess water is collected and reserved for future use. In the context of increasing water stress, the installation of rainwater harvesting (RWH) systems represents a valuable and effective solution to reduce the use of drinkable water consumption for domestic uses not only in arid and semi-arid areas but also in urban areas Ammar *et al (*2016); Campisano and Lupia (2017); Taffare *et al (*2016). The use of these systems has additional benefits, such as the retaining of flood from rainfall events and the consequent control of floods especially in urban areas. Different studies showed that, in urban catchments, the extensive installation of RWH tanks could be an efficient support for reducing frequency and peak of storm water flood. In England, Gerolin *et al* (2010) quantified the flood reduction related to RWH tanks installed in three locations for a wide range of scenarios. This study revealed that, when the average annual supply is smaller than the annual household demand, an increase in the RWH tank size leads to greater retention of flood and reduction in the flood volume and peak Gerolin *et al (*2010). In China, Nanjing district, a study by Zhang *et al* (2012*)* found that the rainwater harvesting system has a good performance in mitigating urban waterlogging problems where it reduced flood volume by 13.9%, 30.2% and 57.7% during the maximum daily rainfall, annual average maximum daily rainfall and critical rainfall, respectively Zhang et al (2012). In evaluating the performance of RWH systems in storm water flood control, Palla *et al* (2017) analysed an installation of RWH tanks in a residential urban block in Genoa, Northern Italy. The study showed a 33% average reduction of peak flow and a 26% reduction of drained rain volume Palla *et al* (2017). Furthermore, a study by Teston *et al* (2018) assessed the impact of RWH on flood reduction in a condominium of houses in Curitiba, Southern Brazil, in different scenarios, found a reduction in peak flow even if the impact of the RWH system on drainage is affected by some factors related to buildings, tank capacity, rainfall characteristics, and land use Teston *et al* (2018).

2.8 Summary of Reviewed Literature.

The global perception and practice of rainwater harvesting vary across different regions and countries. In terms of perception and awareness, globally, there is a growing recognition of the importance of rainwater harvesting as a sustainable water management practice. This perception is being driven by factors such as water scarcity, climate change, and the need for decentralized water supply systems. Rainwater harvesting is often viewed as an environmentally friendly practice that reduces pressure on existing water resources, mitigates storm water runoff, and contributes to water conservation. Furthermore, rainwater harvesting is seen as a way to promote community participation, self-sufficiency, and resilience in water management, particularly in areas with limited access to centralized water supply systems.

In terms of practice, geographical variations, type systems and rainwater usage play a critical role. The practice of rainwater harvesting varies across regions and countries due to differences in climate, water availability, socio-economic conditions, and cultural factors. In addition, rainwater harvesting systems can range from simple techniques like roof catchment systems and storage tanks to more complex setups that involve filtration, treatment, and distribution networks. Further, it has been established that the harvested rainwater can be used for various purposes, including domestic uses (such as drinking, cooking, sanitation), irrigation, and livestock, watering, and recharging groundwater. In some cases, rainwater harvesting is integrated with other water sources, such as municipal water supply or groundwater, to ensure a reliable and sustainable water supply. Apart from that, the adoption of rainwater harvesting practices is often influenced by supportive policies, regulations, incentives, and awareness campaigns implemented by governments and non-governmental organizations.

2.9 Research Gap

According to Nega and Kimeu (2002) Rainwater harvesting is one solution to the problems of water shortage in the drier areas of Africa, but its implementation presents a number of challenges, of which storage is the main one. Many people in rural areas who would like to harvest rainwater lack the resources to do so. Conventional stone, brick or Ferro cement tanks are costly, and therefore there is a great need for cheaper alternatives. Despite the growing importance of rainwater harvesting both in rural and urban areas, there remains a significant research gap in understanding what rainwater harvesting really is, its benefits and different factors affecting the adoption of this technology. Very few studies have been done in this country and there is generally little information on this subject matter. Bridging this gap is crucial for developing targeted interventions and strategies that would effectively promote the adoption and sustainability of rainwater harvesting initiative in Mutama-Bweengwa area. This study will therefore add on the information gap which will be beneficial to the water resource managers as they consider rainwater harvesting as an option to the current water challenges the country is facing.

CHAPTER THREE: DESCRIPTION OF THE STUDY AREA

3.0 Introduction

This chapter describes the study area in terms of its physical location, hydrology, climatic characteristics and the socio-economic activities.

3.1 Location of the Study Area

The Mutama-Bweengwa catchment is located in Pemba District in the Southern Province of Zambia. Pemba district is situated along the Lusaka–Livingstone Road, midway between Lusaka and Livingstone. Mutama-Bweengwa is located in the South-Western part of Pemba district. It is hydrologically located in Lower Kafue Sub-Catchment. Mutama-Bweengwa sub-catchment comprises of Bweengwa River system which contributes significantly to the Kafue Flats. The hydrological sub-catchment area for Mutama-Bweengwa, is approximately 2305.8 km^2 and the length of the river from headwaters to its confluence is 99 km Tena *et al* (2021). Figure below 1 shows the location of Mutama-Bweengwa.

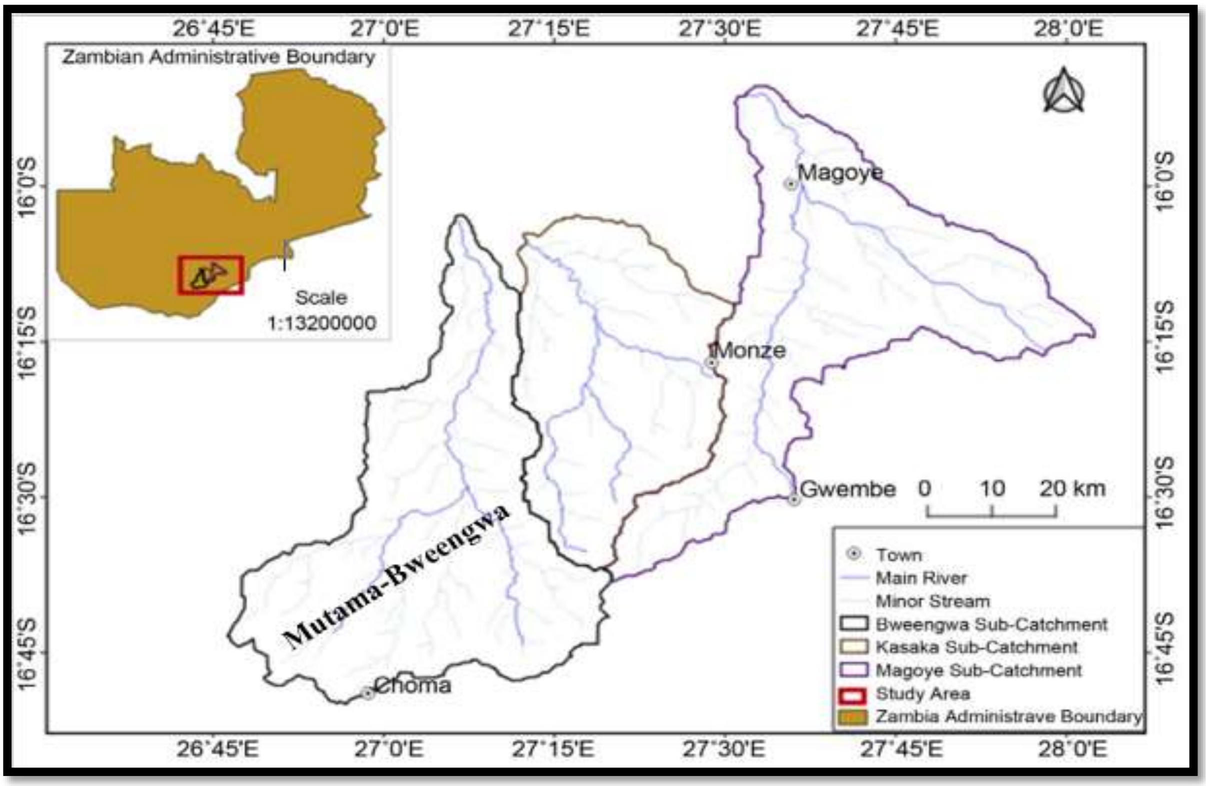

Figure 1: Location and hydrology of the study area.

Source: Tena *et al* (2021:283).

3.2 Climate

The mean annual rainfall and temperature ranges between 650 mm to 800 mm and between 12˚C - 26˚C respectively (WARMA, 2018). The highest temperatures are normally experienced from October to December. However, during the rainy season, temperatures fall considerably. The lowest temperatures are normally experienced in the months of June and July. The rainy season potentially begins in October until the start of April. Additionally, the highest rainfall is recorded in January. Mutama-Bweengwa sub catchment is located in Agro-ecological Zone which has a warm semi-arid conditions.

3.3 Vegetation, Topography and soils

In the sub-catchment, farmland used primarily for subsistence crops has grown in recent decades, contributing to the degradation of natural forests. The sub-catchment's level landscape portions are grasslands with sporadic trees and are vulnerable to flooding because of increased runoff. In the sub-catchment, floodplain grasslands, *termitaria* grasslands, and woodlands are the most prevalent vegetation types Tena *et al* (2021). The sub-catchment lies within an elevation ranging from approximately 1225 m to 1000 m above sea level Bäumle *et al (*2012). It contains a range of aerosols, glycols, histolsols and podzols types of soils, respectively ZMD (2019)

3.4 Socio-economic activities

The 2022 estimated population for Pemba district, in which Mutama-Bweengwa is located, was 101,021, in which 48,950 are male while 52071 are female with an average annual population growth rate between 2010 and 2022 3.5 ZamStats (2022). The local people of Mutama-Bweengwa are largely subsistence farmers who depend on rain-fed agriculture and livestock raring. Brick-moulding, sand mining, logging and charcoal production are some of the land-use activities in the catchment Tena *et al* (2021). Mutama-Bweengwa is in Pemba district. The main ethnic group in the town are the Tonga people. Prominent educational institutions found here are Pemba Basic School, Pemba High School, Jembo Mission High School and Kasiya Secretarial College. Pemba was declared a district by the late President Michael Chilufya Sata in 2012. Before that, it was part of Choma District.

Land use in Pemba District is typical of other smallholder areas in Zambia who practice in the rainy season including livestock rearing throughout the year, figure 2 below shows its land use.

Fields, where crop production is carried out, are individually owned while grazing areas, dams, and boreholes that are constructed by the government or Non-Governmental Organizations are considered common property Musungu (2020); Sichoongwe *et al (*2014). Thus, most households practice mixed crop-livestock farming thereby creating close interaction between crop and livestock production through crop residues that are used to feed the animals and manure to fertilize the crops (Musungu, 2020).

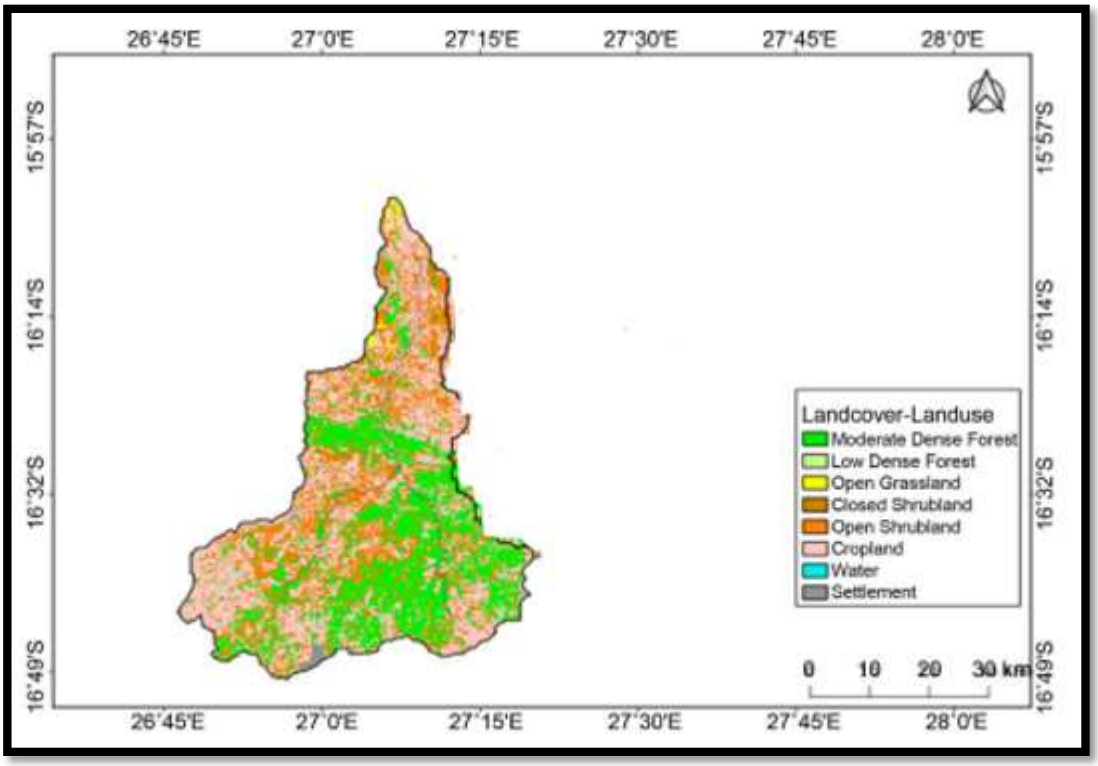

Figure 2: Landuse and Landcover of the Mutama-Bweengwa sub-catchments.

Source: Adapted from Tena *et al* (2021:284)

3.5 Reasons for choosing Mutama-Bweengwa as a study area

The area was chosen for this study because this sub-catchment is affected by limited availability of water which is of strategic significance to the socio-economic development Tena *et al* (2021). The benefit of rainwater harvesting for enhancing food security in Mutama Bweengwa sub-catchment and poor knowledge with regard to the real causes of low adoption rate or failed adoption process due to inadequate participation by residents is another reason why this area was chosen Musungu (2020).

The collection, capturing or diverting rainwater for various productive usages is widespread; especially when it comes to agriculture purposes, soil and water conservation and it has been implemented in numerous projects Muchanga (2020).Various international organizations and institutions conduct substantial research on methods to augment water availability for various purposes. It is because of this backdrop that the researcher chose to undertake the study in this area so as to focus on the on-going community based project by GIZ. Muleba (2018) illustrates that water supply programs are essentially built upon three basic components namely; technology, people (community) and institutions. He further claimed that the right match of the components s believed to result to successful rainwater harvesting projects.

Mutama-Bweengwa sub-catchment area also gives a regional representative of the large part of the Southern Province, in terms of climatic characteristics, socio-economic background, and inaccessibility to important resources like water Tena *et al* (2021). The area is located in Agro-Ecological Region which is the medium rainfall region. Thus, the findings of this will replicate most parts of the Southern region of Zambia.

Hence, the result of the study may contribute fundamental knowledge and information that will be used by policy makers, development project planners during the design and implementation rainwater-harvesting structures.

CHAPTER FOUR: METHODOLOGY

4.0 Introduction

This chapter looks at the methods which were used in carrying out this research. A combination of both qualitative and quantitative research methods were used. This is so because of the nature of the study which needed a comprehensive understanding and interpretation of rainwater harvesting among the residents of Mutama-Bweengwa of Pemba district in Southern province of Zambia.

4.1 Research Design

A research may be qualitative or quantitative depending on the nature of the data to be collected and the methods used to collect data. This study used mixed methods. A mixed methods study combines quantitative and qualitative data collection and analysis in one study (Creswell, 2004). Individually, these approaches can answer different questions, so combining them provided the researcher with more in-depth findings. In addition, it provided stronger evidence and more confidence in the findings. This design intended to explore and analyze how the community of Mutama-Bweengwa practice rainwater harvesting. The study was done using both primary and secondary data sources. This assisted the researcher to obtain in-depth information on the context of rainwater harvesting systems for the amelioration of the problem of water scarcity in the area. It also gave valid and stronger evidence with high level of confidence of the findings. The study employed convergent parallel design. Using this design, the researcher collected quantitative and qualitative data at the same time and analyzed the data separately. This is the most common and well-known approach to mixed methods Creswell (2004), Plano Clark et al (2003). The purpose of this design was to obtain different but complementary data on the same topic Morse (1991) so as to understand the research problem. The specific data collection methods were an amalgamation of direct observation and semi-structured interviews. According to Patton (1990) this design also brought the differing strengths and non-overlapping weaknesses of quantitative methods (large sample size, trends, and generalization) with those of qualitative methods (small, details, in depth).

4.2 Philosophical assumptions

According to Guba (1990), this component of academic research process ensures that there is consistency of the methodology and methods used with the ontological and epistemological assumptions of a particular philosophy of science Guba (1990). The study used both positivism and social constructivism. This is because the semi-structured interviews were more informed by pragmatism while the key informant interviews were more towards subjectivism. This research used the assumption that reality is not independent but socially constructed and can have varied meanings. Thus, there is reality independent of the researcher which can be known and the aim is to uncover that reality and the relationship between the researcher and what is to be known. Epistemologically, the knowledge obtained and discussed in this research was subjective because it was socially constructed based on how resident's mental processes perceived and interpreted rainwater harvesting Connole (1993). Following this philosophical viewpoint, researchers pursuing mixed methods employ both qualitative and quantitative standpoints to accomplish their target or goal.

4.3 Target population

The study was conducted in Mutama-Bweengwa, South-western part of Pemba district in Southern province. The study targeted residents residing in the sub-catchment area. Household heads were selected as the eligible participants in the study. Data from the chief retainers at the palace showed that there were 20000 households in the area and the majority of households in this area were brick moulders, charcoal burners and smallholder farmers who depended on rain-fed agriculture for survival. The study targeted also officers from GIZ, the local people (villagers) within Mutama-Bweengwa, agricultural officers, officers from water resources management authority (WARMA), officers from the department of water affairs (DWA), civil societies and traditional authorities.

4.4 Sampling Techniques, Procedure and Sample Size

This research used a combination of both non-probability and probability sampling design which included purposive sampling and simple random sampling techniques. The former is a form of non-probability sampling in which researchers rely on their own judgment when choosing members of the population to participate in their surveys Bernard (2002) and it was used to select key informants. Purposive sampling was used because the information amassed through this technique had a low margin of error, it was time saving, money saving and gave the researcher opportunity to collect information from reliable and key informants Cresswell and Clarke (2011). Simple random sampling is a technique where each unit of the population has an equal probability of inclusion in the sample Bryman (2012) and it was used to select respondents randomly. Every resident in Mutama-Bweengwa area had an even chance and likelihood of being selected in the sample. The selection of respondents entirely depended on luck or probability. It is a fair method of sampling and it helps to reduce any bias involved compared to any other sampling method involved. Furthermore, the population of Mutama-Bweengwa is high (101021) thus, the researcher thought simple random sampling were the best sampling techniques.

Household survey using semi-structured interviews were done on 379 household heads with a population size of 20000 households (based on the register provided by the village headmen), 95% confidence level and response distribution of 0.5. According to Smith (2004), a sample size is positively related to power. A small sample (less than 30 units) may only have low power while a large sample has high statistical power. Increasing the sample size enhances power. When the study has a large enough sample, every observation that is added to the sample only marginally increases power. 379 residents were sampled using a village register which was supplied by traditional leaders; either the chief or senior village heads. Using the village register, a random sequential number was assigned to each resident in the area, in this case each household head was assigned a number which acted as an ID number. The numbers assigned to each household head were then written on different pieces of papers. Each number on its own piece of paper and the pieces of papers were put in a carton box. The researcher randomly picked 379 numbers from the box, with each number corresponding to the name of the household head in order to create a sample. Before picking a number, the researcher ensured that the numbers were well mixed by thoroughly shaking the box so that everyone had an equal chance of inclusion in the sample. The 379 that were picked made the study sample.

Further, 11 key informants were sampled using homogeneous purposive sampling. The researcher was aware that there a project by German Agency for International Cooperation (GIZ) which catered part of the study area. Hence there was need to ensure that the participants included a combination of both participants and non-participants in the GIZ project. These Targeted key informants were 2 officers from GIZ, 1 from agricultural office, 2 farmers residing within the catchment, 1 from water resources management authority (WARMA), 1 officer from the department of water affairs, 2 civil societies, and 2 from traditional authorities.

4.5 Data Collection tools and Procedure,

4.5.1 Primary Source

A semi-structured interview was used to collect primary data from the resident farmers (villagers). It focused on demographic characteristics of the respondents, practice of RWH, knowledge and perceptions of rainwater harvesting and its benefits. A semi-structured interview had both closed-ended and open-ended questions. Closed-ended questions were designed for the purpose of getting the intended data in a more systematic way and the open-ended questions allowed respondents to express their experiences, knowledge and perceptions on rainwater harvesting. Semi-structured interviews were administered to household heads. This method of data collection was selected because it encourages two-way communication Creswell (2009). Further, Creswell (2009) states that questions can come from both the interviewer and the respondent which allows for a comprehensive discussion of the topic under study. It also allows for open-ended responses from participants for more in-depth information. This tool allowed the respondents to express themselves as widely as possible.

Interviews were administered to key informants. These officials were from Ministry of Agriculture GIZ, water resource management (WARMA), civil societies and traditional authorities. The researcher interviewed two informants from each of the aforementioned departments and one from Department of Water (DWA). Informants were selected based on their expertise and experience on perceptions of rainwater harvesting as well as interactions with local farmers.

4.5.2 Observation

Utilization of direct observation was very vital. The direct observation was used in order to directly see what people do (behavioral lifestyles and physical settings of the community) rather than relying on what they say they do and the observation was done anywhere in the study area. According to Reinharz (2011), observation method of data collection involves seeing people in a certain setting or place at a specific time and day. An observation checklist was used to collect observational data. The variables used were water, rainwater harvesting techniques/tools and methods. The researcher used these variables because they are the most cited factors of rainwater harvesting Below et al (2010). Residents of Mutama Bweengwa area were engaged and affected by the aforementioned factors, hence the reason to use these variables.

4.6 Data Analysis

The collected data was processed and analysed using both qualitative and quantitative data analysis methods. Descriptive statistics were used to summarize quantitative data in charts and graphs**.**The primary data included the data collected through semi-structured interviews and observations. Thus, analysis of this data included content and thematic analysis. This involved classification of words and phrases that are related to the same content into major themes Creswell (1994). There are various approaches to conducting thematic analysis. In this research, the researcher followed the most common six step procedure: familiarization, coding, generating themes, reviewing themes, defining and naming themes and writing up. Thus, after the summary of the findings from the interview questions, the main emerging themes and ideas were manually coded, synthesized and quantified into percentages and presented in form of tables of frequencies and percentages as descriptive statistics. This method was chosen as it is a flexible approach to qualitative analysis that enables researchers to generate new insights and concepts derived from data. This also allowed the actual prevailing pattern, themes and phrases of the research findings to emerge from the data rather than be controlled by factors predetermined prior to their collection and analysis.

4.7 Validity and Reliability

The researcher ensured validity and reliability by checking the consistency of results across time, across different observers and across part of the study itself. Additionally, the researcher was also checking how well the results correspond to established theories and other measures of the same concept. In ensuring validity, the researcher used appropriate methods of sampling. To produce valid generalizable results, the population that was researched was clearly defined. It was made up of people from a specific geographical location and profession. In addition, the study had enough participants which was a microcosm of the population in Mutama-Bweengwa. To ensure reliability, the methods of data collection were applied consistently. Questions were phrased the same way throughout the study.

4.8 Ethical Obligation

The following ethical considerations were done before conducting the study.

4.8.1 Seeking Permission

Ethical clearance to conduct the study was obtained from the University of Zambia, Directorate of Research and Graduate Studies (DRGS). Before going into the field, the researcher obtained permission from the local authorities to conduct a research in their area. These included the Chief, village headmen and ward councillors. This helped the researcher to carry out the study without resistance from the community.

4.8.2 Privacy and Confidentiality

The researcher safeguarded the privacy and identity of all the respondents. It was made clear right from the start that information obtained from the study would be treated with strict confidentiality, and will be used only for the intended research purpose. Participants' personal characteristics was not disclosed to anyone. Additionally, respondents were told before they assented to participate in the study that the researcher would like to publish the findings of the study.

4.8.3 Informed Consent

The researcher gave respondents sufficient information on the study in order for them to make informed decisions about their participation. It was made clear that any participant would be free to withdraw from the study at any time. No respondent was forced to give information during the study.

4.8.4 Covid Guidelines

The researcher bought masks which were used during data collection. Social distance during interviews was strictly followed

4.9 Limitations of the study

1. The research was conducted in 2022 when the covid-19 restrictions were still observed. Thus, some respondents were not very free to interact during the interviews. However, the researcher distributed the face masks to all the participants in the interviews to ensure that they were free during the interview.

2. The major limitation was in the distribution and collection of semi-structured interviews. There were no people at some households and the researcher had to revisit some homes until the task was successfully conducted.

3. The researcher could not access the latest population of Mutama-Bwengwa in terms of number of women and men. Retainers at the palace only had the total number of households for the study area.

CHAPTER FIVE: RESULTS

5.0 Introduction

This study investigated how residents of Mutama-Bweengwa of Pemba district perceive rainwater harvesting. Therefore, it focused on three main objectives, namely; (i) to examine rainwater harvesting practices among the residents of Mutama-Bweengwa. (ii) to find out the factors influencing the rainwater harvesting practices and (iii) to analyse the pros and cons of rainwater harvesting technologies. This chapter presents the findings of the research study and is organized into three main themes based on the above-stated research objectives.

5.1 Demographic Characteristics of Respondents in Mutama-Bweengwa Area.

The information on the gender and age of the respondents were collected and presented in the following subsections.

5.1.1 Gender and Age Range

A total of 379 respondents were interviewed. The majority of the respondents were male (51%), while female accounted for 49%. The results in Table 1 shows the age range of small-scale farmers involved in the study. Results reveal that the youngest respondents, both male and female, were about 21 years old while the oldest male and female respondents were 69 and 66 years old, respectively. Out of the eleven key informants interviewed, 8 where male while 3 were females and their age varied with the eldest being 47 and the youngest being 24. Out of the eleven key informants, six were from the Ministry of Agriculture, two worked for GIZ and three were from the Ministry of Water and Development. Their work experience in the water sector varies from 10 years being the longest to 2 years being the least.

Table 1: Distribution of participants by age and gender.

Sex	N	Mean	StDev	Youngest age	Oldest age
Female	186	41.1	11.6	21	66
Male	193	42.8	13.0	21	69
Total	379	42.0	12.4		

5.1.2 Education level of participants

The level of education of small-scale farmers who were involved in the study was established. The results showed that small scale farmers attained various levels of education ranging from primary to tertiary including some who never attended any formal education. Figure 3 shows the education levels of respondents. The figure shows that, on average, there were more primary school level participants followed by those who did not attain any formal education. 51.58% represented male participants and 47.25% represented female participants who had primary education as the highest level of education attained. 42.11% of the male participants did not attain any formal education with 5.79% and 0.53% attaining secondary and tertiary education, respectively, as the highest level of education. The results further showed that 49.45% of the participants had no formal education, while 2.75% and 0.55% of the female participants attained secondary and tertiary education levels, respectively.

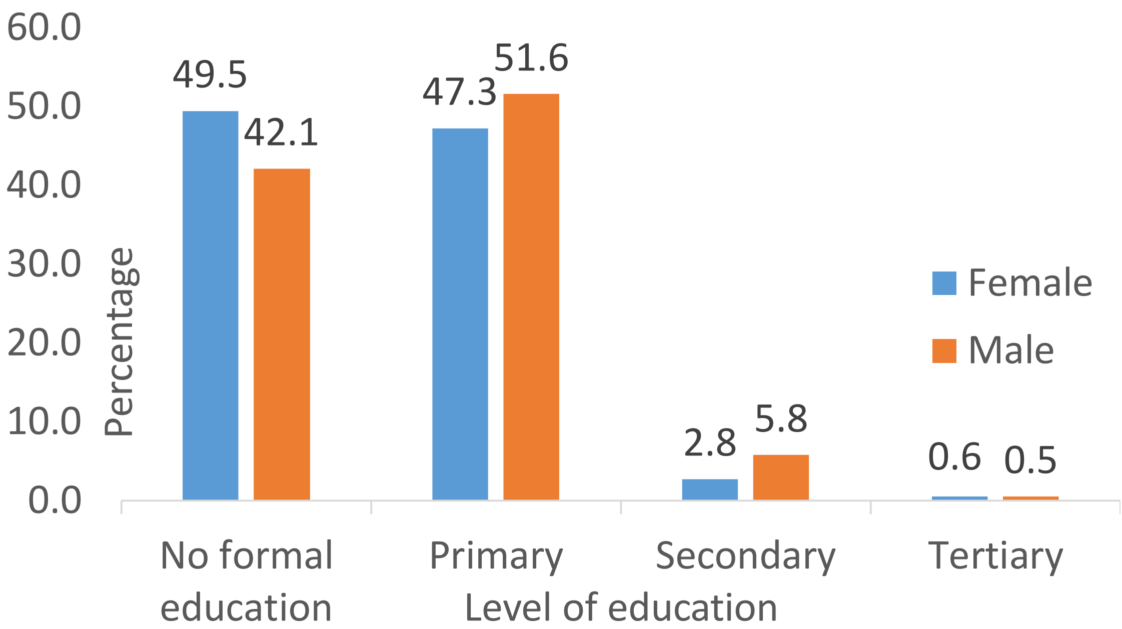

Figure 3: Education Levels of participants

Source: Field Work Data: 2022

5.1.3 Period of Residence in Mutamwa-Bweengwa of Pemba District

The period in which a small-scale farmer lived in Mutama-Bweengwa of Pemba district was established for all the participants. The data was necessary to determine whether or not a participant would give a true reflection of lived experience in the study area.

Figure 4 shows that the majority of the respondents (49.84 percent) indicated that they had been staying in Mutama-Bweengwa, Pemba district for a period of 11-20 years. 28.5 percent were a second majority who stated that they had stayed in Mutama-Bweengwa for 1-10 years. Then 11.57 percent of participants lived in the area for 21-30 years. 13.46 percent of respondents had lived in Mutama-Bweengwa area for more than 30 years while 2.64 percent of the respondent lived in the area for less than a year. This means that the majority of the participants had the lived experience in the study area and thus gave a true reflection of their lived experience in the study area.

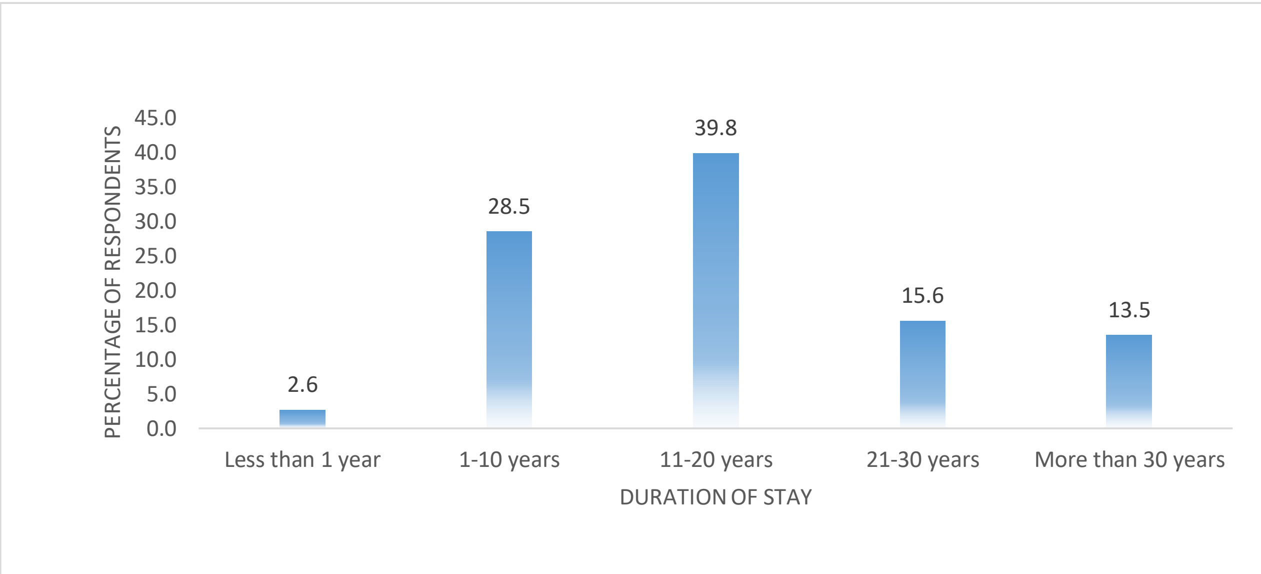

Figure 4: Period of Residence in Mutama-Bweengwa area.

Source: Field Work Data: 2022

5.1.4 Household size and income

The study established the average number of individuals per household as well as the monthly income per household. On average, the household size for most residents of Mutama-Bweengwa was found to be seven (7). All the participants had a monthly income of not more than ZMW 3000, except for two whose income range was between 3001 - 6000 ZMW.

5.1.5 Knowledge of rainwater harvesting

The level of knowledge and experience of rainwater harvesting amongst the residents of Mutama-Bweengwa was established. The researcher first found out how accessible water is to the residents and the quantities accessed per day. About 34 percent of the respondents understood rainwater harvesting as the process of collecting and storing rainwater for use in future, 24.9 percent understood rainwater harvesting as being conserving and storing rainwater, 10.3 percent view rainwater as gathering rainwater off the surface, 0.3 percent and 0.3 percent of the respondents understood rainwater harvesting as being blocking run off and that water is life respectively. Thus, the majority of the respondents have a basic understanding of rainwater harvesting.

5.1.6 Experience and accessibility

The study found out how long the respondents been practising rainwater harvesting. In terms of experiencing or practicing rainwater harvesting, 99.47 percent of the respondents said they had practiced at least a form of rainwater harvesting and only 0.53 percent of the respondents said they have never practiced any form of rainwater harvesting. From the 99.47 percent who practised rainwater harvesing, 36.51 percent have been practising for 1-20 years, 54.23 percent for 11-21, 4. 76 percentage for 21-30 years and 3.17 percent and 1.32 percent of the respondent said they have been practising rainwater harvest for less than a year and more than 30 years, respectively. Figure 5 shows the length of rainwater harvesting of the respondents. Thus, the majority of the residents of Mutama-Bweengwa have experienced and practised rainwater harvesting.

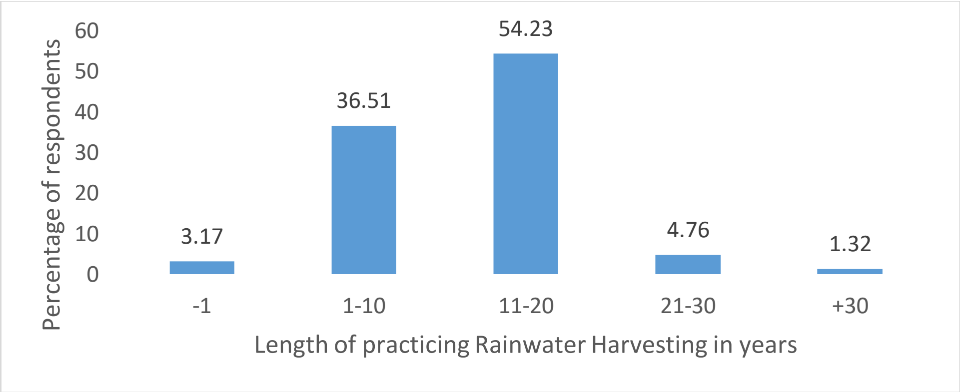

Figure 5: The length of Rainwater Harvesting by respondents in Mutama-Bwengwa

Source: Field Work Data: 2022

5.2. Methods of Rainwater Harvesting used in Mutama-Bweengwa Community

There are various methods of rainwater harvesting. The knowledge of rainwater harvesting methods by the respondents was established. The main rainwater harvesting methods used in Mutama-Bweengwa community include use of buckets at 96.6%, wells at 96.6%, dams at 93.2%, trenches at 5.5%, soilbands at 16.3%, water tanks at 9.2%, ponds at 22.1% and contours at 21.8%. Out of all these,the use of buckets, wells and dams are the dominant methods as shown in Figure 6 .

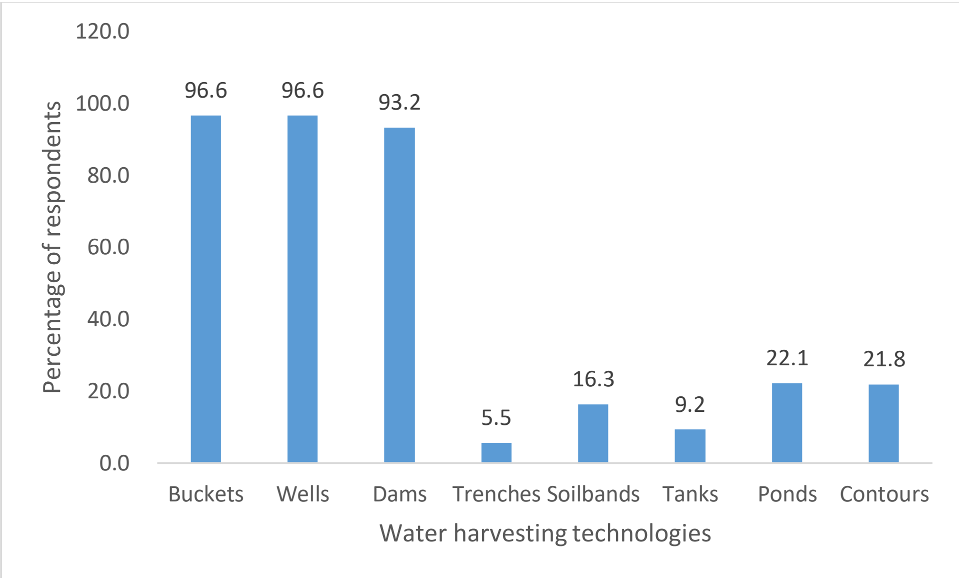

Figure 6: Rainwater harvesting techniques used in Mutama-Bweengwa Community.

Source: Field Work Data: 2022

5.2.1 Recommended Methods of Rainwater Harvesting for Mutama-Bweengwa community.

Rainwater harvesting is an excellent method for collecting and utilizing rainwater in rural areas. It helps conserve water, reduce reliance on external water sources and can be used for various purposes such as watering, livestock and household needs. When choosing the rainwater harvesting method for a specific area, there are things to consider such as the available space, water demand, water quality and so on Malambo and Huang (2012). According to Figure 7, recommendations on methods of rainwater harvesting for Mutama-Bweengwa community were as follows; 96.8% recommended the use of wells, 95.5% of the respondents recommended the use of small dams, and 95% recommended the use of buckets especially if they were to own houses with suitable roofings. 28.4% recommended ponds, 16.8% recommended tanks while another 16.8% recommended soil bands, 6.3% recommended for trenches and the 0.5% recommended for the use of check dams method. Furthermore, out of the eleven key informants four stated that they would recommend rooftop rainwater harvesting, landscape trenches and soil bunds methods for rainwater harvesting, while two said that they would recommend using rivers, tanks and underground water. The last five recommended the use check dams which are accessible and affordable for most of the residents of Mutama-Bweengwa. In adding, all the eleven key informants agreed that they would recommend water harvesting in Mutama-Bweengwa catchment because it is an efficient way of using water for farming and animals, watering areas for agriculture activities and increase water availability and decrease water shortage in the dry season and during dry spells as check dams, soil bunds and trenches are already being used for water harvesting rainwater.

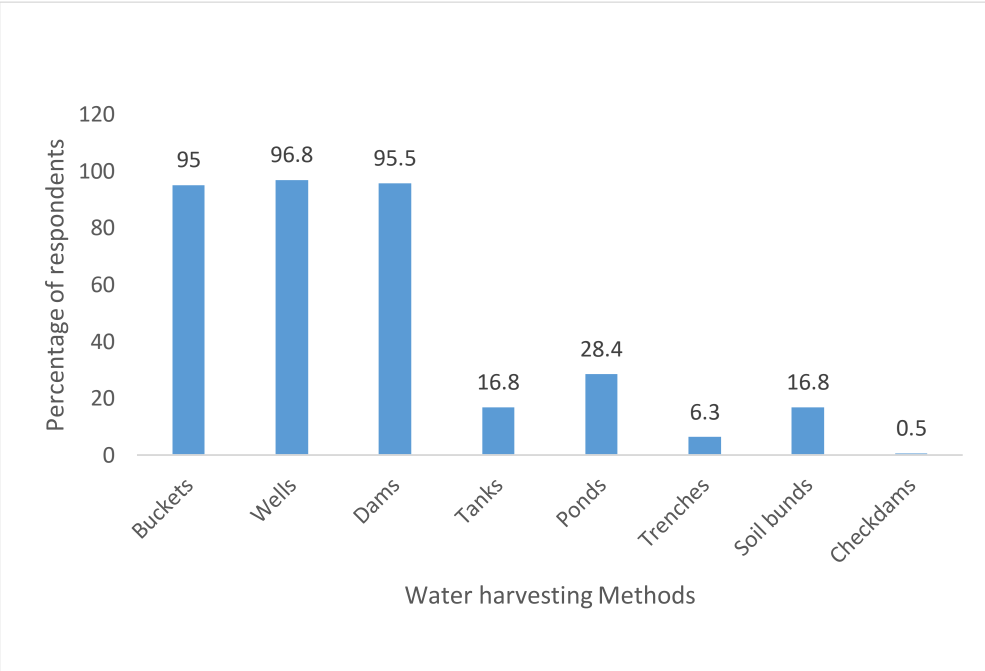

Figure 7: Recommended methods of Rainwater Harvesting in Mutama-Bweengwa area

Source: Field Work Data: 2022

5.3 Factors Affecting Rainwater Harvesting

There are several factors that can affect the implementation and effectiveness of rainwater harvesting in rural communities. These factors can vary depending on the specific context and location, but here are some common ones for the people of Mutama-Bweengwa community: Inadequate rainfall, lack of public awareness on the utilization of rainwater, lack of skilled human labour, etc.

5.3.1 Factors that may promote Rainwater Harvesting in Mutama-Bweengwa

There are many factors that may promote rainwater harvesting in Mutama-Bweengwa community. Having interviewed the residents of Mutama-Bweengwa community, the study revealed a number of factors that could promote rainwater harvesting in their community. Figure 8 shows that the majority (98.1%) of the respondents pointed out that good amount of rainfall is the key factor that would promote rainwater harvesting in Mutama-Bweengwa area. 90.5% said that good roofing materials, 82.2% pointed at the involvement of the government and NGOs, 70.3% of the respondents said availability of technology is another factor. 60.4% said that good environment contributes positively to successful rainwater harvesting, 33.8% said that adequate capital is vital while 7.5% responded that educational awareness in terms of trainings has a positive impact on rainwater harvesting.

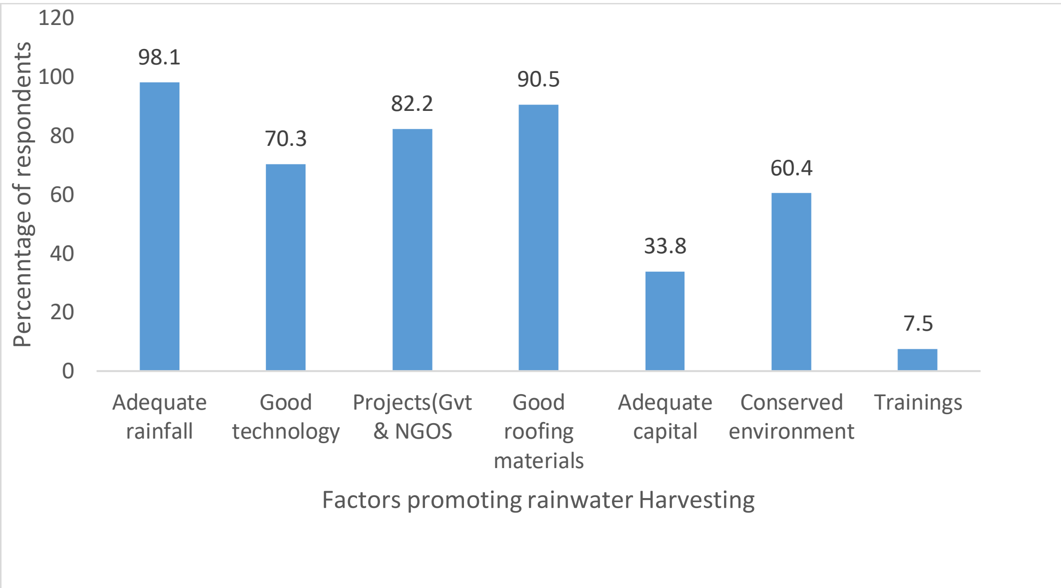

Figure 8: Factors promoting Rainwater Harvesting techniques in Mutama-Bweengwa Community.

Source: Field Work Data: 2022

5.3.2 Factors that may hinder Rainwater Harvesting in Mutama-Bweengwa Community

The knowledge on the understanding of the factors that may hinder rainwater harvesting implementation in Mutama-Bweengwa was sort from the residents. According to Figure 9, the majority of the respondents (94.5%) cited inadequate rainfall as a key factors that would hinder rainwater harvesting. 65.2% stated that a degraded environment hinders rainwater harvesting,55.5% mentioned lack of resources,24.7% said community resistance,23.1% said that lack of awerness,8.2% said high cost of structures while another 8.2% responded that limited storage facilities was one of the factors that may hider rainwater harvesting.3.9% of the responded said population increase may also hinder rainwater harvesting. Seven out of the eleven key informants said that inadequate rainfall, increase in population and cost of structure and sedimentation and human activities were some of the factors that would hinder RWH in Mutama-Bweengwa. Two said that eroded land, lack of resources and lack of technical knowledge on method of rainfall water harvesting would be some of the factors that would hinder RWH.

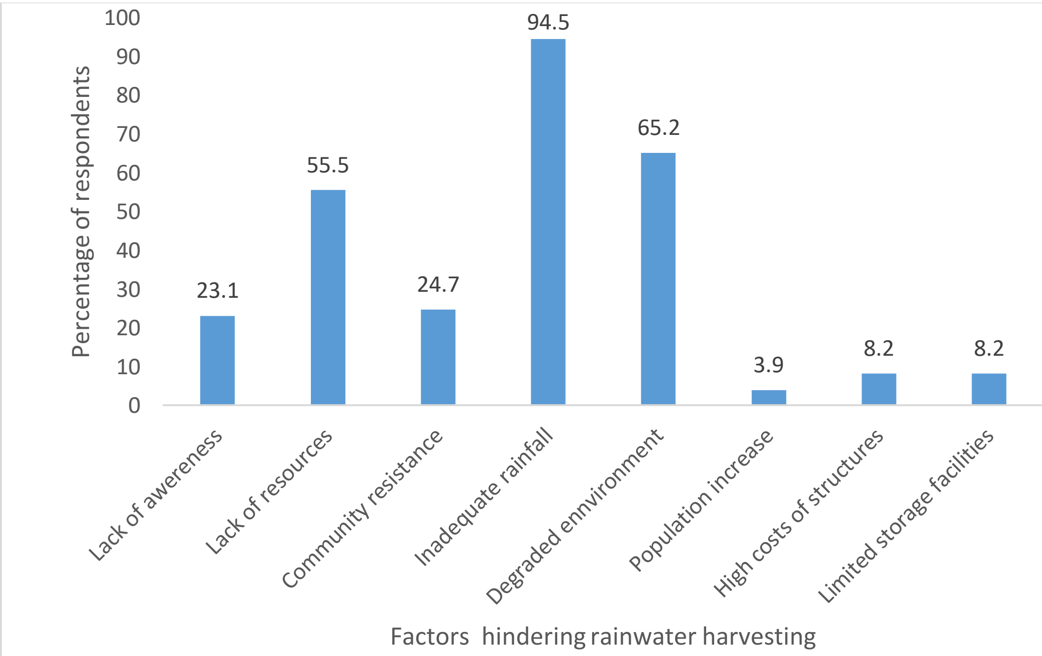

Figure 9: **Factors hindering Rainwater Harvesting Techniques in Mutama-Bweengwa community.**

Source: Field Work Data: 22

5.4 The possible Pros and Cons of Rainwater harvesting in Mutama-Bweengwa Community

A number of advantages and disadvantages of rainwater harvesting were cited by the respondents in Mutama-Bweengwa community.

5.4.1 The possible pros of Rainwater harvesting in Mutama-Bweengwa Community

As perceived by the residents of Mutama-Bweengwa community, rainwater harvesting could have a number of advantages if it was to be implemented in their community. 32% of respondents stated that rainwater would be used for domestic purposes, 22% stated that rainwater practices help to reduce degradation, 16% mentioned that it reduces floods, 14% argued that it decreases demand of water, 11% responded that rainwater harvesting helps for irrigation purposes, 4% respondent stated that it is helpful for gardening and livestock while 1% of the respondents said that rainwater harvesting supports craft. Out of all these advantages, it came out so strongly from the majority that rainwater harvesting would provide water for domestic use and reduce land degradation. The responses from the respondents are as shown in Figure 10.

Key informants cited the following as the main reasons for using rainwater harvesting in Mutama-abweengwa: agricultural benefits, water scarcity, self sufficiency, cost effective and environmental sustainability.This is because the area is a farming community and rainwater is needed for this purpose.

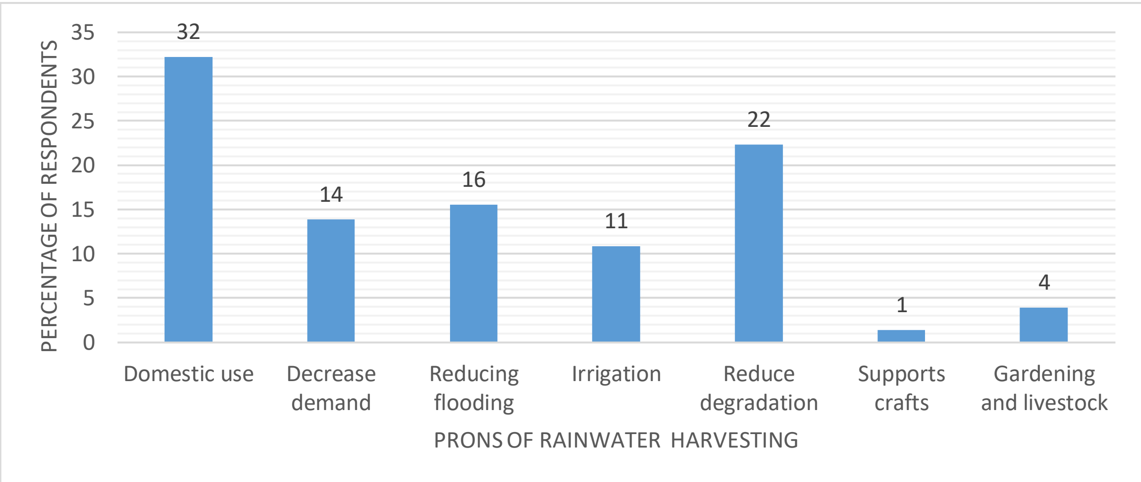

Figure 10: **Advantages of rainwater harvesting in Mutama-Bweengwa community.**

Source: Field Work Data: 2022

5.4.2 The possible cons of Rainwater harvesting in Mutama-Bweengwa Community

The most keyed disadvantages included damage to the environment with 69.4% respondents, storage limitations was another con mentioned by 53.6% respondents, 52.8% stated that lack of adequate rainfall is not a desirable attribute of rainwater harvesting, 12.7% stated that that ack of purification facilities is a disadvantage of a rainwater harvesting system. 1.6% of the responded indicated that destruction to the environment was also co of rainwater harvesting. Figure 11 shows the disadvantages of rainwater harvesting.

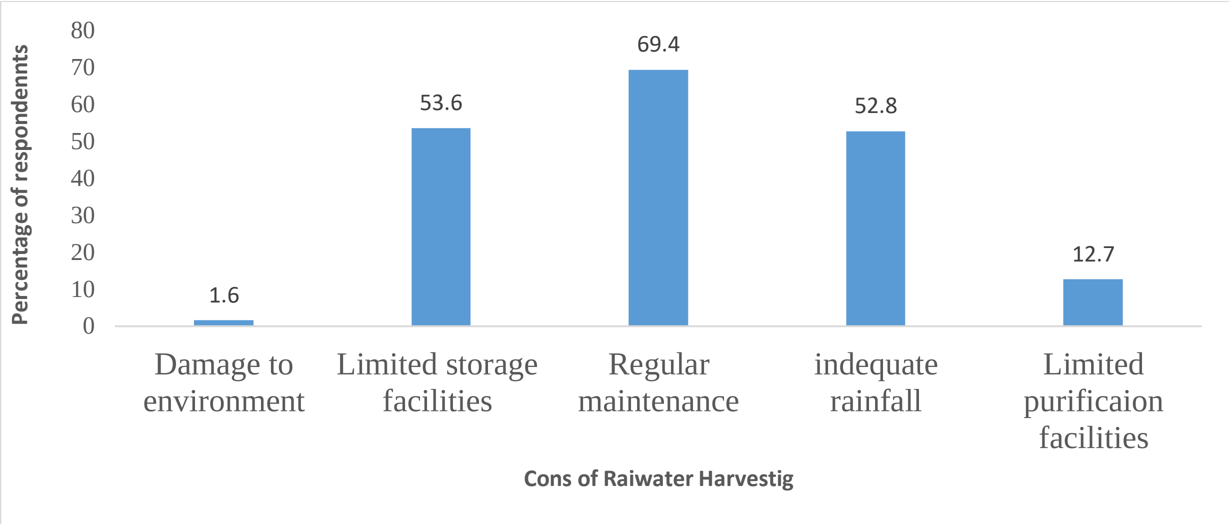

Figure 11: **Disadvantages of Rainwater harvesting in Mutama-Bweengwa community.**

Source: Field Work Data: 2022

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CHAPTER 6: DISCUSSION OF RESULTS

6.0. Introduction

This chapter presents a discussion of the findings presented in chapter five. The discussion is themed according to the objectives of the study. The study shows that most respondents were male. This could be attributed to the cultural practices in the area where men are primarily responsible for decision-making in the households and community. The men are involved in crop and animal production, whereas, the women play a secondary role in the household chores within the community. This could have significant effects on the adoption and implementation of rainwater harvesting. There could be the low likelihood of women being involved in adoption decisions in this regard, despite women being the ones involved in fetching water.

6.1. Rainwater harvesting methods among the residents of Mutama-Bweengwa Community.

This section discusses the key points regarding methods of rainwater harvesting methods among the people of Mutama-Bweengwa community.There are various methods of rainwater harvesting that are practiced and reommended by the respondents was established. The main rainwater harvesting methods used in Mutama-Bweengwa community include use of buckets, wells, dams, trenches, soilbands, water tanks, ponds and contours. Out of all these,the use of buckets, wells and dams are the dominant methods . This is mainly due to the nature of the environment and the rainwater harvesting catchment area. For example, the rooftop rainwter harvesting is impossible because most of the houses are grass thatched as shown in Figure 12. Three of the respondents explained as follows;

> *'For me, it is difficult to harvest the rainwater because the roof of my house is made of grass. When I tried to harvest in a bucket, the water was very dirty (brown water) with some grass in it. So i prefer using wells,' (Respondent 255) .*

> "Inspite of me not having roofings made out of iron sheets I still harvest rainwater using backets by simply putting the backets in an open space when the rain comes, I have no any other option since water is found vwey far." (Responded 30)

"If rainwater is retained and harvested within the catchment area, the use of wells is the best as I only have to dig a few meters into the ground to find water since the water table is raised high,"

(Responded 76)

A

B C

Figure 12: Type of houses in Mutama-Bweengwa community

Source: Field Work: 2022

This corresponded with Huang and Malambo (2016) who defined rainwater harvesting as a simple process or technology used to conserve rainwater by collecting, storing and conveying it from rooftops, open grounds and roads into dams, wells, trenches and soil bunds. From the methods practiced in the catchment area, it clearly shows that the majority of the respondents have a basic understanding of rainwater harvesting. This could be attributed to the fact that there is a similar project around the area being conducted by the GIZ as some of the residents could have been part of the project.

Muleba (2018) also indicated that rainwater harvesting can be done by using rooftops through gutters and storing the water in tanks. He further said that Rainwater harvesting can be done using rivers, buckets, shallow wells, streams and dambos. These are among the traditional rainwater harvesting methods practised not only in Mutama-Bweengwa community but also in other parts of rural Zambia, though at a very small scale.This is in line with Handia *et.al* (2003) who said that many rural residents may not be familiar with the technical and modern methods of rainwater harvesting, such as the design and construction of storage systems, filtration methods, and water treatment. Thus, there would be need to educate the community mainly on adavnced RWH systems as the small and traditional ones are already being practiced. There was also good number of rainwater harvesting techniques observed that are being used and these included built-up weirs and gabions constructed that keeps rainwater within the catchment area. This corresponds with Sibanda (2012) who said that any successful rainwater harvesting system requires sustainable sructures with suitable designs according to the nature of the catchment area.

For Mutama-Bweengwa community, most of the respondents recommended the use of buckets, wells and small size dams for rainwater harvesting methods. Furthermore, out of the eleven key informants four stated that they would recommend rooftop rainwater harvesting, by using landscape trenches or soil bunds method for water harvesting, while two said that they would recommend using rivers, tanks and underground water. The last five said they would recommend using check dams which are accessible and affordable for most of the residents of Mutama-Bweengwa.

6.2 Basic Components and characteristics of a Rainwater Harvesting System

It's worth noting that the exact configuration and components of a rainwater harvesting system can vary based on factors such as local regulations, climate conditions, water demand, and available resources. The respondents' knowledge of the components of a rainwater harvesting system in Mutama-Bweengwa community was assessed. Majority of the respondents understood the main components of a rainwater harvesting system as being catchment areas that include roofs of buildings and open spaces, storage units that can be a barrel or a tank, gutters and downspouts.

A rainwater harvesting system consists of several basic components that work together to collect, store, and distribute rainwater for various purposes. The knowledge on the basic components of a rainwater harvesting system of the people of Mutama-Bweengwa was assessed. 70.6% of the respondents cited catchment areas that include roofs of buildings and open spaces as the basic component of a rainwater harvest system. 45.6% indicated conveyance mechanism which transports the water falling on the catchment area to the storage unit while a few indicated storage units that can be a barrel or a tank. four out of the eleven key informants said a basic rainwater harvesting system comprises of collecting surfaces such as rooftops, gutters or channels of direct water and storage tanks, three said it can be done by the systems such as reservoir, pumps, channels, and collection body, while four said by using systems such as conveyances pipes, gutter, storage facility and sedimentation chamber.

A good rainwater harvesting system should have certain characteristics to ensure its effectiveness and efficiency. This study further assessed the knowledge of people of Mutama-Bweengwa community on the characteristics of a good rainwater harvesting system. The majority understand that a good rainwater harvesting system should have good storage capacity, good environment and there should be enough rainwater water. It was also found out that a good rainwater harvesting system has trenches, soil band as well as trees and grass, Figure 13 shows a catchment area with newly planted trees located at Mutama-Bweengwa community.

Key informants stated that a good harvesting system must have a good water holding capacity, completeness apportioning of water proper design and easy maintained, while one said it must have a good catchment area. Furthermore, they stated that different structures are used in rainwater harvesting include underground tanks, raised tank, and natural reservoirs, while other two said soil bunds, check dams, gully plugs, roof water harvesting structures, trenches and ponds. In addition, eight agreed that the existing structures in Mutama-Bweengwa area can be used at household level but not community level, while two said only natural reservoirs can be used and the other two said trenches and soil bunds can be used. It was noticed that most of the residents that practice rainwater harvesting use small scale surface rainwater harvesting techniques and tools such as buckets, small wells /check dams; and very few use rooftop techniques mainly because there are few with houses roofed with iron sheets, the majority are grass thatched houses.

Figure 13: Open space catchment area with newly planted trees.

Source: Field Work Data: 2022

6.3 Factors influencing Rainwater Harvesting practices in Mutama-Bweengwa.

There are a number of factors, positive and negative, that would promote or hinder rainwater harvesting in Mutama-Bweengwa community. Based on the responses from both residents and key informants interviewed, it can be argued that the success of rainwater harvesting in Mutama-Bweengwa community relies on the adequacy of rainfall. The respondents stressed that Mutama-Bweengwa experiences irregular or insufficient rainfall which would limit the effectiveness of rainwater harvesting systems. This corresponds well with Tena et al (2021) who said that Mutama-Bweengwa catchment falls in the agro-ecological region which is hard hit with climate change and receives inadequate rainfall. Residents also indicated that they may find it challenging to collect and store sufficient rainwater for their needs when rain falls, which is the main source is as it remains inadequate. This corresponds well with Chomba and Sichingabula (2016) who said that rainwater availability is subject to seasonal variations, and this can affect perceptions of rainwater harvesting. According to Erickson (2012), among the eco-climatic conditions, rainfall quantity and pattern are the most important factors. Rainfall quantity is the most unpredictable variable in the calculation. Hence reliable rainfall data for a period of at least ten years is considered to calculate the potential rainfall supply for a given catchment. The rainfall data from the nearest stations with comparable conditions are preferably considered. Rainfall pattern or the number of annual rainy days influences the need and design for rainwater harvesting. The need for the collection of rainwater in a region is more if the dry period is long or the annual rainy days are fewer. During dry seasons, when rainwater is scarce, the limitations of rainwater harvesting systems may become more apparent, leading to the expressed concerns about their reliability.

The nature of the catchment was another factor mentioned that affect rainwater harvesting. The type of houses occupied by the residents are grass thatched which makes it difficult for them to harvest rainwater from the rooftops. Muchanga (2020) also argued that people in rural areas only practice traditional methods of rainwater harvesting due to the nature of the catchment areas and the most common method is surface rainwater harvesting. In Mutama-Bweengwa area, most of the houses are grass-thatched in. As such, rooftop rainwater harvesting, for instance, becomes a challenge to the residents. This means that after harvesting, the water need to be filtered and purified in order to increases its quality and purity. Contamination from roof materials, storage tanks, or improper maintenance practices can affect water quality as argued by Tena et al (2012). Ensuring water safety and implementing appropriate treatment measures is crucial. According to Stanford (2010), the capital cost of rainwater harvesting systems is highly dependent on the type of catchment, conveyance and storage tank materials used. Compared to deep and shallow tube wells, rainwater collection systems are more cost effective, especially if the initial investment does not include the cost of roofing materials. However, Hurtang (2002), reported that the associated cost of rain water harvesting system are for installation, operation and maintenance. Of the costs installation, the storage tanks represent the largest investment which can vary between 30 and 45% of the total cost of the system dependent on a system size. A pump, a pressure controller and fittings in addition to plumber's labor represent other major costs of the investment.

Lack of technical knowledge on methods of rainwater harvesting was another factor cited that would hinder RWH in the area. Some residents of Mutama-Bweengwa perceptions regarding rainwater harvesting highlighted technical challenges. These included issues related to the design, construction, and maintenance of rainwater harvesting systems. Lack of technical expertise, poor construction practices, and inadequate maintenance can undermine the effectiveness and sustainability of such systems and poor catchment environment as a result of soil erosion. This corresponds well with Mwamila et al (2016) and Syed (2008) who argued that the problem is that farmers and communities do not have the knowledge or the means to implement suitable techniques in the appropriate way. In addition it is necessary that some be tested under current conditions. According Erickson (2012), the problem is that farmers and communities do not have the knowledge or the means to implement suitable techniques in the appropriate way. In addition it is necessary that some be tested under current conditions. The capacity of the communities and the national research program and extension services needs enhancement in the area of water harvesting. Conditions are now suitable for mobilizing human and financial resources for improving the situation under appropriate physical and socioeconomic environments. Two of the respondents stated that implementing rainwater harvesting system would not be a problem as they have basic idea though they need expertise orientation to manage and maintain the system.

''*I have some ideas about managing the rainwater harvesting system but I may need the experts to come and train me on how to manage and maintain the system*'' *(Responded 22).*

"*Lack of technical skill and knowledge cannot allow me to build durable home structures to enable me harvest rainwater right at my home." (Responded 117*)

Capital was another factor mentioned by the residents that affects the adoption of rainwater harvesting practices, 80% of these farmers are poor and therefore cannot afford most of the rainwater harvesting structures. According to Murgor (2013), one of the potential limitations to farmers in adopting modern technologies and inputs is the financial related problems such as cost of hired labour is too high, transportation cost is high for agricultural products, cost of construction material is high and lack of credit access or shortage of capital. It is difficult to increase agricultural sector productivity without efficient credit facility, given the fact that the majority of farmers are resource-poor.

Overall, overcoming these hurdles require community engagement, education (sensitisation), and support from local authorities and non-governmental organizations (like the GIZ which is currently undertaking a project on RWH) within and around the Mutama-Bweengwa community. However, the current situation in Mutama-Bweengwa area is that there may be a lack of local technical capacity and access to appropriate technologies, including trained.

"*The community does not corporate when given a task such as collection of stones for weir and gabion building as most of them expect to be paid after the exercise," (Key Informant).*

Another key informant highlighted that;

"*There is no support in terms of funds from the government that support rainwater harvesting, hence*

Available resources may allow the exercise to be conducted in this community"

The other issue in hindering rainwater harvesting in the area is the nature of the catchment area. Most of the houses are grass-thatched. As such, rooftop rainwater harvesting, for instance, becomes a challenge to the residents as argued by Kasuba and Muzyamba (2009). The type of houses occupied by the residents are grass thatched which makes it difficult for them to harvest rainwater from the rooftops. In this respect, the people of Mutama-Bweengwa can safely practice surface rainwater harvesting as rooftop harvesting is almost impossible In few homes and school were rooftop rainwater harvesting is done, the water need to be filtered and purified in order to increases its quality and purity. Contamination from roof materials, storage tanks, or improper maintenance practices can affect water quality. Ensuring water safety and implementing appropriate treatment measures is crucial.

Population increase is another factor that influences rainwater harvesting in Mutama-Bweengwa area. Residents said that rapid population due to early marriages and polygamy has got negative effects on the little harvested rainwater due to its high demand for various livelihood activities such as brick moulding, gardening, livestock keeping and domestic use. Hence most of the wells, small dams, rivers and ponds tend to dry up earlier than expected within a short period of time as shown in Figure 14. According to Bashar *et al* (2018), in the recent years, rainwater harvesting (RWH) has received an increased attention as one of the most promising alternative source of water, which can be used to partially offset the increasing demand of clean water globally. Due to climate variability, excessive groundwater extraction and increasing water stress with the rapid growth of the population, water supply has become a major global concern Bashar *et al* (2018).

Figure 14: Harvested rainwater drying up due to inadequate rainfall and poor facilities to retain it within the catchment.

Source: Field Work Data: 2022.

Addressing these challenges requires a multi-dimensional approach that involves community engagement, capacity building, awareness campaigns, technical support, and policy reforms. Collaboration between government agencies, Non-Governmental Organisations, community-based organizations, and other stakeholders is crucial to overcome these barriers and promote the successful implementation of rainwater harvesting projects in Mutama-Bweengwa Catchment. Three of the key informants said government has never tried to introduces rainwater harvesting while nine said yes government has been involved and it is currently in partnership with GIZ and other stakeholders in implementing a pilot study on rainwater harvesting in the area as shown in Figure 15. Furthermore, government has constructed some dams which are used in the area. Additionally, government is engaging with stakeholders in sensitization on the benefits of rainwater harvesting and by partnering with NGOs in sensitization on the benefits of rainwater harvesting and partnering with NGOs

In addition, rainwater harvesting projects (like the GIZ led project in Mutama-Bweengwa) are often implemented through community participation and involvement. This participatory approach fosters a sense of ownership and empowerment within the community, as they are actively involved in the planning, implementation, and maintenance of rainwater harvesting systems. The GIZ project seem to have greatly contributed in pioneering awareness of the importance of rainwater harvesting amongst the residents of Mutama-Bweengwa community.

A B

Figure 15: Built-up weirs constructed to keep the water within the catchment, dugout trenches/soil bunds

Source: Field Work Data: 2022

6.4 Pros and Cons of Rainwater harvesting technologies.

Understanding and addressing residents' attitudes towards rainwater harvesting technologies is crucial for a successful implementation of rainwater harvesting. It requires community engagement and participation, awareness campaigns, education, and addressing concerns related to water quality, affordability, and cultural aspects. This corresponds well with Sibanda (2012) who said that by involving residents and tailoring approaches to their specific needs and circumstances, the acceptance and adoption of rainwater harvesting technologies can be enhanced. Some residents had a positive attitude towards rainwater harvesting as they recognized the benefits of collecting and utilising rainwater. Among the benefits include provision of water for domestic use, promoting environmental sustainability, etc. This means that these individuals would actively support and participate in rainwater harvesting.

For the residents of Mutama-Bweengwa, rainwater harvesting would be a means to enhancing water security in the area where access to clean water is limited. It is perceived as a reliable and sustainable water source that can supplement other water sources such as boreholes. Respondents in Mutama-bweengwa area said that rainwater harvesting had a lot of advantages such source of water for domestic uses and decrease of water demand. Furthermore, they said that rainwater harvesting is often associated with improved health outcomes in rural communities. Kasuba and Muzyamba (2009) agrees by stating that providing a source of clean water, rainwater would reduce reliance, for the residents of Mutama-Bweengwa on unsafe water sources such as rivers and ponds, which can be contaminated with waterborne diseases as these are also drinking points for the livestock. Kumweenda and Mwiinga (2019) also argued that harvested rainwater is a very good source of immediate home use such as cooking, drinking and washing. Out of all these advantages, it came out so strongly from the majority that rainwater harvesting would provide water for domestic use and reduce land degradation. Figure 16 shows some rainwater harvested using tools by GIZ project and a woman coming from fetching harvested water.Three of the respondents said:

> *'I use the harvested water mainly for watering my vegetables, washing, and for bathing, said one responden,' (Responded 18)*

Other respondents added and said:

> *'I use harvested rainwater drinking and also giving the cattle. This water is harvested through shallow wells. This has really helped me because most of the time, the rains*

will stop early and the nearby rivers become dry. So I use water from the wells to drink and also for our animals, although it is not enough,' (Respondent 305)

"Rainwater harvesting will help me as I will not be walking long

distances to go and fetch water from the rivers. So, I really need it here," (Responded 14*)*

A B

C

Figure 16: Harvested water for domestic use using tools constructed by GIZ.

Source: Field Work Data: 2022

Residents said Rainwater harvesting would be a way to increase agricultural productivity. Further, Muchanga (2020) argued that by capturing and storing rainwater, farmers could irrigate their crops during dry periods, mitigating the impact of drought and ensuring better yields. Apart from that, rainwater harvesting would be a cost-effective solution compared to other water supply options, such as drilling boreholes or installing piped water systems. Residents of Mutama-Bweengwa responded that irrigation was one of the uses of the harvested water in the sub-catchment area. Most of the residents own fields where they grow crops annually as well as small gardens that entirely depend on the harvested rainwater especially during the dry season as shown in Figure 17. Lay (2010) also argued that limited and erratic precipitation often results in crop failure as well as serious soil and water loss but rainfall harvesting can change the distribution pattern of rainfall runoff in time and space, which would supply humankind with steady water sources to some extent.

A B

Figure 17: Vegetables grown using harvested water from a shallow well.

Source: Field Work Data: 2022

Responded further said that rainwater harvesting provide the possibilities of setting up new ecological systems since there is the reduction of land degradation through the building of rainwater harvesting structures such as weirs, gabions as well as tree planting. . Goyal (2005) agreed by stating that the sustainability of the watershed project depends on the ecological and technical parameters like construction of water harvesting structures, soil and water conservation measures. Sivanappa (2007) further corresponded by saying that water is part of the larger ecosystem on which bio diversity depends. Precipitation, converted to soil and groundwater and thus accessible to vegetation and people, is the dominant pre-condition for biomass production and social development in dry lands. The amount of available water is equivalent to the water moving through the landscape.

Respondents further said that rainwater practices have cons and these include limited purification and storage facilities, regular maintenance, inadequate rainfall and damage to the environment. Some responded claimed that the dug structure such as trenches and soil bunds end up being eroded land if abandoned. Syed (2017) argued that the maintenance cost of the dug and built rainwater harvesting structures is high. According to Anschutz (2003), the major cost of water harvesting scheme are in the earth and stone work. The quantity of digging of drains, collection and transport of stones, maintenance of the structures will provide an indication of the costs of the scheme. Usually these labour requirements are high. Most water harvesting structures are dug in the dry season and farmers are engaged in other activities like cattle herding or wage labour on plantations or in urban areas. Labour requirements depend very much on power sources available. The choice of the equipment depends on power sources available. In small scale systems labour is mostly carried out using hand tools. Drought animals like oxen, donkeys and horses can be used for ridging and bed making. Simple ridging equipment exist which may be drawn by animals for instance mould board ridges.

CHAPTER SEVEN: CONCLUSION AND RECOMMENDATIONS

7.0 Introduction

This chapter concludes the findings of this study. It is divided into two parts, the first being the conclusion and the second being the recommendations.

7.1 Conclusion

This dissertation explored the practices of rainwater harvesting among residents of Mutama-Bweengwa community. Through an in-depth analysis of the methods of rainwater harvesting practices, factors affecting the practices as well as pros and cons of rainwater harvesting in Mutama-Bweengwa community.

The findings of this study revealed a generally good number of methods used for rainwater harvesting with the most common methods being buckets, wells and check dams. Other methods mentioned by the respondents include trenches, soil bunds, ponds and contours.65% of the residents wish to practice modern types of rainwater harvesting as they believe that they are safer and more durable. However, the traditional practices of water collection and storage were still valued, and the introduction of more advanced rainwater harvesting technologies was seen as a positive step towards modernization while still preserving cultural heritage. The participants recognized the potential benefits of rainwater harvesting, including improved water security, access to clean water and enhanced sustainability. For the residents of Mutama-Bweengwa, rainwater harvesting would be a means to enhancing water security in the area where access to clean water is limited. It is perceived as a reliable and sustainable water source that can supplement other water sources such as boreholes. Respondents said that rainwater harvesting had a lot of advantages such source of water for domestic uses and decrease of water demand. They appreciated the opportunity to diversify their water sources and reduce reliance on unreliable or distant water supplies. However, the study also identified some concerns and challenges that need to be addressed. Lack of technical skilled labour emerged as a significant concern among the respondents, highlighting the need for technical labour force for the advanced system. Affordability and accessibility were also identified as potential barriers, emphasizing the importance of considering the financial capabilities and resources of the community in implementing rainwater harvesting systems.

Community engagement and participation were found to be crucial factors in fostering practices of rainwater harvesting. Involving residents in the planning, implementation, and maintenance of rainwater harvesting projects not only enhanced their understanding of the technologies but also facilitated a sense of ownership and empowerment within the Mutama-Bweengwa community.

Overall, this dissertation contributes to the growing body of knowledge on rainwater harvesting in rural settings in general, specifically in Mutama-Bweengwa area. The findings provide valuable insights for policymakers, educators, and practitioners involved in implementing rainwater harvesting initiatives in similar settings. By understanding and addressing the rainwater harvesting practices among residents of Mutama-Bweengwa area, this dissertation contributes to the broader goal of promoting sustainable water management practices and improving access to clean water in rural communities.

7.2 Recommendations

This study recommends for:

1. There is need a need to provide training and extension services to resident farmers so as to develop and disseminate more effective and affordable types of rainwater harvesting and storage technologies as alternatives and to design, develop alternative policy instruments and social institutions that facilitate adoption of Rainwater harvesting and storage practices.
2. The actors of rural development such as International Development Agencies, Private Sector, Non-Governmental Organizations as well as Government should intensify the awareness on rainwater harvesting so as to gain the adoption and acceptance by most people. Long-term impacts of rainwater harvesting in Mutama-Bweengwa area which is necessary for the future generations.
3. The actors of rural development such as International Development Agencies, Private Sector, Non-Governmental Organizations as well as Government should provide a broader understanding of the practices, methods and challenges of rainwater harvesting in Mutama-Bweengwa and the country at large especially in areas where projects are already being undertaken.
4. The government through Ministry of local Government and rural development should support residents of Mutama-Bweengwa by providing soft loans with low interest. This will enable residents to engage in better livelihood activities such as farming and gardening that generate income rather than charcoal burning practice which has destroyed the green

environment which acts as a catchment area. The soft loans can also be used as capital for the installation of rainwater harvesting systems so as to reduce water demand.

5. Further studies to identify policy gaps, institutional challenges, and opportunities for strengthening the enabling environment for rainwater harvesting at the national, regional, and community levels are to be conducted by various stake holders.
6. The government through the Ministry of Agriculture, Green Economy, Water and Supply need an intensification of sensitisation on the benefits of rainwater harvesting countrywide especially in areas that lack water.
7. There is need for the government and other actors of rural development to conduct a community based training on the construction and maintenance of standard surface rainwater harvesting systems which are more suitable in Mutama-Bweengwa area. Currently, such trainings are only conducted by GIZ on a very small scale.

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APPENDICIES

Appendix 1: Questionnaire

SEMI-STRUCTURED INTERVIEWS FOR LOCAL PEOPLE OF MUTAMWA-BWEENGWA AREA.

TOPIC: PERCEPTIONS OF RAINWATER HARVESTING AMONG RESIDENTS OF MUTAMA
BWEENGWA OF PEMBA DISTRICT

INTRODUCTION

My name is Sinzala Muchimba, a postgraduate student at the University of Zambia Department of Geography and Environmental Studies, conducting research on the topic, **Perceptions of Rainwater Harvesting among Residents of Mutama-Bweengwa of Pemba District**.
You have been selected to answer the questions as honestly as possible. The data you will provide will be treated with the highest degree of confidentiality it deserves and will be used for academic purpose only

SECTION A: PERSONAL INFORMATION

1. 1. Sex

   Mark only one oval.

   ⬭ Female
   ⬭ Male

2. Age:…………….

3. 3. Highest level of education

   Mark only one oval.

- No formal education
- Primary
- Secondary
- Tertiary
- Other:

4. How much do earn per month?

Mark only one oval.

- K1 – K 3000
- K3001 – K6000
- K6001 – K 9000
- Above K 9000

5. How long have you lived in this community?

Mark only one oval.

- Less than 1 year
- 1-10 years
- 11-20 years
- 21-30 years
- More than 30 years

6. How many Males are at this household?

7. How many Females are at this household?

SECTION B: KNOWLEDGE AND EXPERIENCE OF RAINWATER HARVESTING

8. State the water availability and access across seasons from the (River, open well, hand pump, piped, other, specify).

Mark only one oval per row.

	Every day	Most days/4-6 days per week	Few times/1-3 days per week	None at all
Dec-Mar	⬭	⬭	⬭	⬭
Apr-July	⬭	⬭	⬭	⬭
Aug-Nov	⬭	⬭	⬭	⬭

9. What quantities of water do you access per day for domestic use?

Mark only one oval.

- 0 litres – 20 litres
- 21 litres – 40 litres
- 41 litres – 60 litres
- 61 litres – 80 litres
- Above 80 litres

10. Have you ever practiced rainwater harvesting in your community?

Mark only one oval.

- Yes
- No

11. If yes to question (9), for how long have you done so?

Mark only one oval.

- Less than 1 year
- 1-10 years
- 11-20 years
- 21-30 years
- More than 30 years

12. Which method of rainwater harvesting have you used before?

Tick all that apply.

- Buckets
- Wells
- Dams
- Ponds
- Tanks

Other:………

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13. What are the reasons that made you to resort to rainwater harvesting?

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14. Which method of rainwater harvesting would you recommend for your area?

Tick all that apply.

- Buckets
- Wells
- Dams
- Ponds
- Tanks

Other:………

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15. What are the reasons for your recommendation?

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SECTION C: AWARENESS OF RAINWATER HARVESTING METHODS AND TECHNIQUES

16. What do you understand by rainwater harvesting?

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17. What methods of rainwater harvesting do you know?

Tick all that apply.

☐ Buckets

☐ Wells

☐ Dams

☐ Ponds

☐ Tanks

Other:………

…………….

18. Tick all the basic components of a rainwater harvesting system which you know?

Tick all that apply.

Catchment areas that include roofs of buildings and open spaces.

- [ ] Storage units that can be a barrel or a tank.
- [ ] Conveyance mechanism which transports the water falling on the catchment area to the storage unit.
- [ ] Gutters and downspouts
- [ ] Leaf screens and roof washers
- [ ] Cisterns or storage tanks
- [ ] Other:…………………………..

19. What are the characteristics of a good rainwater harvesting System?

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20. Can the existing structures in your community be used for rainwater harvesting?

Mark only one oval.

- ⬭ Yes
- ⬭ No

SECTION D: PERCEPTION OF RAINWATER HARVESTING

21. Tick all possible benefits your community can get from rainwater harvesting?

Tick all that are applicable.

Tick all that apply.

- [ ] Flood mitigation
- [ ] Increasing groundwater levels
- [ ] Greater water availability for irrigation
- [ ] Prevents soil erosion and ooding
- [ ] Provide water for livestock

Other:……………………………

………………

22. Who would benefit most from rainwater harvesting?

Mark only one oval.

- Women
- Men
- Girls
- Boys

23. What is the common use of harvested rain water?

Mark only one oval.

- Cooking and drinking
- Washing and bathing
- Gardening.
- Livestock

Other:……………

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24. Explain your answers to question 23?

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SECTION E: FACTORS AFFECTING RAINWATER HARVESTING

25. What are the factors that promote rainwater harvesting?

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26. What factors do you think would hinder rainwater harvesting in your community?

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27. What are the advantages of rainwater harvesting?

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28. What are the disadvantages of rainwater harvesting?

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29. Any other comments

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Appendix 2: Key Informants Interviews

TOPIC: PECEPTIONS OF RAINWATER HARVESTING AMONG RESIDENTS OF MUTAMA-BWEENGWA OF PEMBA DISTRICT.

INTRODUCTION

My name is Sinzala Muchimba, a postgraduate student at the University of Zambia Department of Geography and Environmental Studies, conducting research on the topic, **Perceptions of Rainwater Harvesting among Residents of Mutama-Bweengwa of Pemba District**.

You have been selected to answer the questions as honestly as possible. The data you will provide will be treated with the highest degree of confidentiality it deserves and will be used for academic purpose only

1. Sex
2. Age
3. Institutional affiliation
4. Years f working on water related issues
5. How accessible is water in Mutama-Bweengwa area?
6. What is rainwater harvesting?
7. What methods are used for rainwater harvesting?
8. Which method would you recommend for the community of Mutama-Bwengwa and why?
9. What are the basic components of rainwater harvesting system?
10. What are the characteristics of a good rainwater harvesting system?
11. What are the different structures used for rainwater harvesting?
12. Can the existing structures in Mutama-Bweengwa be used for rainwater harvesting?
13. Would you recommend rainwater harvesting in Mutama-Bweengwa catchment? If yes, Why?
14. How would communities benefit from rainwater harvesting?
15. Who would benefit most and how?
16. What is the common use of the harvested rain water?
17. What factors promote rainwater harvesting?
18. What factors hinder rainwater harvesting?
19. What is the purpose of rainwater harvesting?

20. Is rainwater safe for drinking?
21. How much space is required to collect rainwater?
22. Has the government ever tried to introduce rainwater harvesting in Mutama-Bweengwa catchment?
23. What steps has the government taken to promote rainwater harvesting in Mutama-Bweengwa catchment?
24. What challenges has the government faced in trying to introduce and implement rainwater harvesting in Mutama-Bweengwa catchment?

Appendix Approver Letter

THE UNIVERSITY OF ZAMBIA

DIRECTORATE OF RESEARCH AND GRADUATE STUDIES

Great East Road Campus | P.O. Box 32379 | Lusaka 10101 | Tel: +260-290 258/291 777
Fax: (+260) 211 290 258/253 952 | Email: director.drgs@unza.zm | Website: www.unza.zm /directorates/drgs

APPROVAL OF STUDY

IORG No. 0005376
HSSREC IRB No. 00006464
REF NO. HSSREC-2024-JAN-041

30th April, 2024

Ms. Muchimba Sinzala
The University of Zambia
P.O. Box 32379
LUSAKA

Dear Ms. Sinzala

RE: **"PERCEIPTIONS ON RAINWATER HARVESTING AMONG RESIDENTS OF MUTABA – BWENGWA OF PEMBA DISTRICT".**

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

REVIEW TYPE	ORDINARY REVIEW	APPROVAL NO. HSSREC:- 2024 - JAN – 041
Approval and Expiry Date	Approval Date: 30th April, 2024	Expiry Date: 29th April, 2025
Protocol Version and Date	Version - Nil.	29th April, 2025
Information Sheet, Consent Forms and Dates	☐ English.	To be provided
Consent form ID and Date	Version - Nil	To be provided
Recruitment Materials	Nil	Nil
Other Study Documents	Questionnaire.	
Number of Participants Approved for Study		

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

CONDITIONS OF APPROVAL

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

- All protocol modifications must be approved by HSSREC by way of an application for an amendment prior to implementation unless they are intended to reduce risk (but must still be reported for approval). Modifications will include any change of investigator/s or site address or methodology and methods. Many modifications entail minimal risk adjustments to a protocol and/or consent form and can be made on an Expedited basis (via the IRB Chair). Some examples are: format changes, correcting spelling errors, adding key personnel, minor changes to questionnaires, recruiting and changes, and so forth. Other, more substantive changes, especially those that may alter the risk-benefit ratio, may require Full Board review. In all cases, except where noted above regarding subject safety, any changes to any protocol document or procedure must first be approved by HSSREC before they can be implemented.

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

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

Yours faithfully,

DR. J. I. Ziwa
CHAIRPERSON
THE UNIVERSITY OF ZAMBIA HUMANITIES AND SOCIAL SCIENCES RESEARCH ETHICS COMMITTEE - IRB

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