FACULTY OF SCIENCE

SCHOOL OF GEOGRAPHY, ARCHAEOLOGY AND ENVIRONMENTAL STUDIES

ASSESSING CLIMATE CHANGE COMPATIBLE SMALLHOLDER WATER MANAGEMENT STRATEGIES IN SOUTHERN DRY LANDS OF ZIMBABWE

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Supervised by

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DECLARATION

I, Pascal Manyakaidze, declare that this thesis, including all the information like figures, tables, graphs, and other illustrations, constitutes my original work except in cases acknowledged and referenced. All processes of data collection, cleaning, and analysis, report writing was conducted by the candidate. The thesis is submitted for the Doctor of Philosophy Degree under the Global Change Institute, University of the Witwatersrand, Johannesburg, South Africa.

Signed: ____________________

On this **2ND** Day of **May**, Year **2023**, **Johannesburg**

The candidate's supervisors certify the above declaration as correct and approve this thesis for submission for the Doctor of Philosophy Degree Geography.

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ABSTRACT

The rise in temperature, rainfall decline and increase in other extreme weather scenarios are some of the global climate change and variability challenges affecting most countries. The global south countries bear the most burden from changes in climate. Communities in dry lands continue to experience increasing pressure from water scarcity due to the increased frequency and magnitude of droughts. Smallholder farmers in dry lands keep counting losses of the accumulated productive assets, which recovery efforts cannot replace. The impact of climate change on Zimbabwe's rainfed smallholder farmers' livelihoods and economies manifest in increased poverty and vulnerability at community levels. Against this background, the research aimed at assessing how smallholder communities in dry lands can adapt to climate change using climate-compatible water management strategies.

The study employed interpretivism, and philosophical realism approaches to gathering empirical evidence in Save and Mazvihwa communal areas in Chiredzi and Zvishavane districts, respectively. Interpretivism and the realism approach enabled the gathering of in-depth qualitative and provided quantitatively driven scientific and statistical data in response to the questions. The study participants were drawn from smallholder farming households, government departments, NGOs/CBOs officials, local authorities, extension officers, traditional leaders, village pump minders and water point committee members. A household questionnaire administered to randomly selected respondents gathered quantitative data, while measurements, direct field observations, focus group discussions, and key informant interviews provided qualitative data.

Evidence from the study indicates the continued increase in climate change and variability-related constraints affecting smallholder water management in drylands. Water harvesting opportunities are not fully exploited, climate and weather information communication is not effectively enforced, institutional arrangements are not utilised effectively, and ecosystems-based water replenishment practice is not in force. The findings of this study highlight that water governance, climate and weather information services, behaviour change, private sector service provider roles, and risk management strategies need integration and implementation within the socio-economic context of the communities facing water stress.

Key contributions to the body of knowledge, governance mechanism and a community of practice are made by the study through revealing gaps, areas of convergence and divergence in policy and practice, leveraging opportunities in climate change, and financial mechanisms. The study presented a “**Systems-based Adaptive Water Management Framework**” that provides sector-wide, multi-level linkages and proven approaches for achieving resilient water management that adapts to multiple scenarios, including ecosystems, financial, political and institutional arrangements. The study concludes that the susceptibility of dry land communities to water stress may be related to aggravating effects of climate change that need a sector-wide approach, accommodating context-based and institutional arrangements.

DEDICATION

To Notice Nathan Manyakaidze and Prosper Manyakaidze, my late father and brother. To my mother, Annastacia Chipo Manyakaidze, for all the enduring love, hard work and sacrifices in upbringing us. For the faith that you ignited in our hearts and the hard work you taught us, may the Lord give Nathan and Prosper eternal rest. To my mother, Annastacia, you are indeed strong in the arms of our Lord Jesus Christ. To the entire Manyakaidze family, let us embrace unit, love, hard work and prayer.

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LIST OF ABBREVIATIONS AND ACRONYMS

3PA	- Three-pronged approach
AEZ	- Agroecological Zone
AGRITEX	- Department of Agricultural, Technical and Extension Services
AI	- Aridity Index
AMC	- Asset Management Committee
ARWR	- Annual Renewable Water Resources
BEAM	- Basic Education Assistance Module
CAMPFIRE	- Communal Area Management Programme for Indigenous Resources
CBPP	- Community Based Participatory Planning
CBO	- Community Based Organization
CCD	- Climate Compatible Development
CSA	- Climate Smart Agriculture
COP	- Conference of Parties
COVID-19	- Coronavirus disease 2019
CPU	- Civil Protection Unit
CSOT	- Community Share Ownership Trust
DDF	- District Development Fund
DRM	- Disaster Risk Management
DRR	- Disaster Risk Reduction
DSD	- Department of Social Development
DTC	- Dip Tank Committee
DVLS	- Department of Livestock and Veterinary Services
DWSSC	- District Water and Sanitation Subcommittee
ECRAS	- Enhancing Community Resilience and Sustainability
ECRIMS	- Enhancing Community Resilience and Inclusive Market Systems
EHT	- Environmental Health Technician
EMA	- Environmental Management Agency
ENSO	- El Nino Southern Oscillation
EWS	- Early Warning Systems
FAO	- Food and Agriculture Organization
FAW	- Fall Army Worm
FDMS	- Food Deficit Mitigation Strategy

FFA	- Food Assistance for Assets
FMD	- Foot and Mouth Disease
GCM	- Global Circulation Model
GDP	- Gross Domestic Product
GMB	- Grain Marketing Board
GNU	- Government of National Unit
GOZ	- Government of Zimbabwe
ICA	- Integrated Context Analysis
IFAD	- International Fund for Agricultural Development
IKS	- Indigenous Knowledge System
ILK	- Indigenous and Local Knowledge
IMC	- Irrigation Management Committee
IPCC	- Intergovernmental Panel on Climate Change
IWRM	- Integrated Water Resources Management
LSA	- Lean Season Assistance
MOHCC	- Ministry of Health and Child Care
MSD	- Meteorological Services Department
NAC	- National Action Committee
NCCRS	- National Climate Change Response Strategy
NCU	- National Coordination Unit
NGO	- Non-Governmental Organization
PPE	- Personal Protective Equipment
PPP	- Public Private Partnership
PSP	- Participatory Scenario Planning
PWSSC	- Provincial Water and Sanitation Subcommittee
RDC	- Rural District Council
RDDC	- Rural District Development Committee
RWIMS	- Rural Water Information Management System
SADC	- Southern African Development Committee
SLP	- Seasonal Livelihoods Programme
SDG	- Sustainable Development Goals
SMS	- Short Message Service
SOP	- Standard Operating Procedure
UN	- United Nations

UNCCD	- United Nations Convention to Combat Desertification
UNDP	- United Nations Development Programme
UNEP	- United Nations Environmental Programme
UNOCHA	- United Nations Office of the Coordination of Humanitarian Affairs
VIDCO	- Village Development Committee
VHW	- Village Health Worker
VPM	- Village Pump Minders
WADCO	- Ward Development Committee
WFP	- World Food Programme
WII	- Weather Indexed Insurance
WPC	- Water Point Committee
ZESA	- Zimbabwe Electricity Supply Authority
ZIMSTAT	- Zimbabwe Statistical Agency
ZIMVAC	- Zimbabwe Vulnerability Assessment Committee
ZINWA	- Zimbabwe National Water Authority
ZRBF	- Zimbabwe Resilience Building Fund

CHAPTER ONE

FRAMES OF REFERENCE

1.1 BACKGROUND TO THE STUDY

The United Nations Food and Agricultural Organization (FA0) highlighted climate change as a long accepted and pressing global problem, with 70 to 80 percent of its impacts hitting hard developing countries' economies and livelihoods (FAO, 2011 & 2016). Global food security and production systems are primarily being hampered by climate change (Ainembabazi, 2018; Bhaga et al., 2021; Ofori et al., 2021). Global temperature records for the period 1850 to 2022 attested to a significant rise, responding to increased atmospheric concentration of greenhouse gases (IPCC, 2022a). The widely accepted reality of climate change induced global warming was testified by Brazier (2015) and Saghir (2016) who concurred that the average global temperatures have been rising, as evidenced by the successive warming in the past three decades. The rise in global temperature was tracked back to the period starting in 1850 (Unganai, 1996). Scientific evidence pointed to the rise in global mean temperature by an average of 0.8 degrees Celsius above the pre-industrial era levels, whilst the sea level has since risen by an average of 15 to 20cm within the same assessed period (Unganai, 1996). Global warming, according to Masih et al. (2014) and UNDP (2017), altered the pre-existing climatic conditions and resulted in increased frequencies at the global level in the occurrence of extreme weather events in response to the El Nino Southern Oscillation (ENSO). The above scholarly views concretise the evidence of climate change-induced temperature rise as the most significant trigger of all climate-related impacts.

Climate change has so far contributed to widespread water shortage (FAO, 2021; OECD, 2022), rise in sea level (World Meteorological Organization, 2020; World Meteorological Organization, 2021), land degradation (FAO, 2021), disruption of ecosystems and loss of biodiversity across the globe (Government of Zimbabwe, 2019b). FAO (2016) highlighted that the impacts of climate change on agriculture and livelihoods vary across geographic locations and regions. These will become increasingly adverse and unbearable over time and potentially catastrophic in marginal areas where the most vulnerable people live. Moreover, these are unstable economies that heavily rely on rain-fed livelihoods (IFAD, 2021; UN, 2021). Notable global climate change scenarios include the heat waves in North America and Australia that have increased the occurrences of veldt fires (Lasco et al., 2011). South American countries, including Bolivia, in 2015/16 declared state of emergency when hit by the worst drought in 25 years that nearly dried up its primary water sources (Roy, 2018; World Meteorological Organization, 2020). Due to climate change, East Africa suffered some of the worst droughts in 60 years, whilst Latin America, the Middle East and North Africa recorded water scarcity and livelihoods fragility due to devastating droughts (Nganga, 2006). Climate change affected most food insecure regions with impacts felt across Sub-Saharan Africa and Asia (Ainembabazi, 2018; FAO, 2016a; Ofori et al., 2021). Stronger frequencies of dry spells and drought resulting in water stress have reduced smallholder farmers' capacity to grow their food crops (Bhaga et al., 2020; World Meteorological Organization, 2020; IFAD, 2021), raise animals (Adaptation Fund, 2020) and manage changes in supporting biodiversity.

High poverty levels intensified livelihoods challenges in globally marginalized communities by limiting agricultural potential (FAO, 2016b). According to Brazier (2018) and Todd & Todd (2021), poverty and climate change continue to reinforce each other and impacting more vulnerable communities. Location of smallholder farmers in rainfall marginal areas has led to their susceptibility to droughts. Land degradation, lack of technology to improve production and lack of economic diversification further exacerbated smallholder farmers' vulnerability to food, water and income insecurity.

Assessments by the United Nations Environmental Programme (Ofori et al., 2021; UNEP, 2012) indicated that the recorded increase in global temperatures and the related extreme weather events could increase climate-related threats and stresses, including drought and increased water scarcity on the African continent. Africa's vulnerability to climate change has gained momentum due to the continent's heavy reliance on critical sectors that are climate sensitive. Agriculture, water, energy and biodiversity were identified as highly sensitive and vulnerable to climate change, regardless of them being critical in food provision, livelihoods and health for most smallholder farmers (Chiriac & Naran, 2020; IFAD, 2021; IPCC, 2019; OECD, 2022; Samu & Akıntuğ, 2020; UN, 2021; Appiah, 2017). The International Food Policy Research Institute (IFPRI) 2050 forecast by crop mode (IFPRI, 2009) projected that average rice, wheat and maize yields would decline by 14%, 22% and 5% in sub-Saharan Africa, due to the unfavourable impacts of the changing change. An estimated 80 percent of the population in Sub-Saharan Africa dwells in rural areas, and 85 percent mainly vulnerable women depend on rain-fed agriculture and biodiversity. Chevallier (2006) and Ziervogel et al. (2008), supported by FAO (2014), attributed Sub Saharan Africa's low agricultural yields and vulnerability to changes in climate and the region's reliance on over 90 percent rain-fed agriculture, despite the increasing levels of water stress. Despite these significant threats, Nhemachena and Hassan (2007) revealed that agricultural activities in sub-Saharan African countries contribute to an average of 15% GDP earnings, employ around 60% of communal population and account for nearly 40% of regional foreign exchange earnings. These changes indicate the importance of climate change to the region's prosperity and development.

Sy (2015) further presented a contradictory scenario and predicament of a Sub-Saharan African region whose greenhouse gas emission levels are very low compared to Europe and America, yet the region is at the receiving end and hardest hit by global warming. The limited availability of resources to build and strengthen sub-Saharan Africa's adaptive capacity and weak response mechanisms makes the region more susceptible to the multiple impacts of the changing climate context (Mach et al., 2016). Weak adaptive capacity perpetuated by a fragile environment and economy threatens smallholder farmers' future and climate-sensitive sectors' sustainability.

In light of the global and sub-Saharan African regional climate change impacts, Zimbabwe was not spared. Brazier (2015) and GOZ (2015) presented evidence from records starting in 1900 indicating that Zimbabwe's average surface temperature has risen by 4 degrees Celsius. Zimbabwe's minimum and maximum average daily temperatures have also risen by around 2.6 ^{O}C and 2 ^{O}C, respectively, since the 1900 assessment period (Brown, 2012). Saghir (2016) further pointing out that drought was a major challenge and a significant threat for smallholder farmers' livelihoods and economy between 1971 and 2012. The frequency of El Nino Southern Oscillation (ENSO) occurrence in the country has increased (Zimbabwe Resilience Building Fund, 2017a). According to the World Meteorological Organization (2014), ENSO is a naturally occurring climate phenomenon whereby the sea surface temperatures are altered due to global changes in atmospheric temperatures. Studies by Unganai (1996), Masih et al. (2014) and Zimbabwe Resilience Building Fund (ZRBF) (2017) have shown that more than 62% of all the El Nino events that affected Zimbabwe resulted in some of the record-breaking droughts that negatively threatened water resources and smallholder rain-fed agriculture. The Zimbabwe Resilience Building Fund (ZRBF) (2017) presented evidence of El Nino frequencies and strengths which continued to increase in drought periods of 1982/83, 1997/98 and 2015/16, as compared to their past occurrences. An analysis indicated that 62% of all the El Nino events in Zimbabwe resulted in below-normal rainfall, which led to droughts and water scarcity. With

80% of Zimbabwe's water used in the agricultural sector and 75% of this sector dominated by smallholder farmers in rural communities, exposure and vulnerability are very high in marginal rainfall areas (Government of Zimbabwe, 2010).

Despite Zimbabwe’s agricultural economy and livelihoods being sustained by rain-fed agriculture, Brazier (2015) and GOZ (2015) revealed that the total amount of rainfall received in the country on average recorded a 5% decrease since 1900. Manyeruke et al. (2013) and Brazier (2015) further noted that the slight reduction in precipitation and the increasing droughts have resulted in the shifting of ecosystems, with a reduction of grasslands affecting grazing animals. Manyeruke et al. (2013) further indicated that climate is changing faster than the adaptation capacity of the country’s cropping and livestock systems. Accordingly, Mugandani et al. (2012) pointed out that the country has experienced major Agroecological Zone (AEZ) shifts, especially in the predominantly arid AEZ IV and V, which became much drier than previously experienced and these regions expanded by 5.6% and 22.6% respectively. The scientific prediction of a 10% reduction in water flows in the Zambezi and Limpopo basins, predominantly AEZ IV and V, as well as the Lowveld regions, further explains the increase in the aridity of the regions because of climate change. These changes have partly contributed to the increase in the country's water demand, which surpassed the available supply by 631 million cubic litres per year (Brown et al., 2002). Frequency of occurrence and the magnitude of droughts continued on the rising trajectory (Bhaga et al., 2021; World Meteorological Organization, 2021) and exposed many smallholder farmers to climate impacts.

The global, regional, and local climate change scenario points to a future where smallholder farmers encounter climate change-related water stress. This climate induced water stress limits farmers' sustainable engagement in productive, resilient and sustainable agriculture to support their livelihoods and agro-based economies. The UNDP and GOZ (2017) revealed that despite a general warming trend, temperature patterns have varied by location, with the temperature being higher in southern Zimbabwe, especially the Lowveld region. UNDP and GOZ (2017) further indicated that the two leading food producing AEZ II and III had shrunk respectively by 49% and 14%, thus pointing to an expansion of arid areas as a result of temperature increase and reduction in annual rainfall. Given the observed climate change-related vulnerabilities in Zimbabwe, the government made efforts to develop the Zimbabwe National Climate Change Response Strategy and the Zimbabwe Climate Policy (Government of Zimbabwe, 2015b, 2016c) and other pieces of legislation, including the Zimbabwe Agriculture Investment Plan

2012 – 2017 (Government of Zimbabwe, 2012a). These were all affected by lack of resources for the implementation of adaptation strategies.

1.2 THEMATIC CONSIDERATION

Some of the areas in Zimbabwe that are greatly impacted by climate change are Chiredzi and Zvishavane districts (Figure 3.1). These two districts have experienced highly variable rainfall and temperatures. These two study areas are in the dry lands and fall within agroecological zones IV and V Mugandani et al. (2012) and Meteorological Services Department (2018 ; 2020). Smallholder farming dominates all agricultural activities in the study locations and agriculture is the primary source of food and income (World Food Programme, 2021). However, for smallholder agriculture to be sustainable, productive and profitable, there must be a reliable water supply for irrigated and rain-fed crop cultivation. Smallholder farmers in the identified dry lands are vulnerable to climate change-induced water stress.

Besides the influence of El Nino Southern Oscillation (ENSO), Zimbabwe's climate is also influenced by relief as rainfall increases with the increase in altitude (Government of Zimbabwe, 2015b). The targeted Save and Mazvihwa areas are in AEZ IV and V that receives erratic rainfall and prone to hazards including crop failure and livestock diseases (Zimbabwe Resilience Building Fund, 2016). Chiredzi receives erratic rainfall of mostly below 450mm while Zvishavane receives around 600 per annum (Government of Zimbabwe and World Food Programme, 2017). In this view, the study was interested in understanding climate change and water-related barriers limiting smallholder farmers' productivity and how vulnerable communities in rainfall-marginal areas can adopt strategies to build resilience against climate-induced water stress.

1.2.1 PROBLEM STATEMENT

Considering the stated research questions and in view of the temporal and spatial variability of rainfall within the rainy season, the southern dry lands of Zimbabwe are characterized by erratic and unpredictable rainfall patterns. This context has resulted in poor performance of the agricultural economy within the domain of poor smallholder farmers in rainfall marginal areas (IFAD, 2016; Mugandani et al., 2012; Zimbabwe Resilience Building Fund, 2017b). In view of this observation, the problem that inspired the carrying out of this study was:

Climate change and variability related water challenges increased the vulnerability of dry land smallholder farming communities to socio-economic and environmental insecurities.

1.2.2 RESEARCH AIM AND OBJECTIVES

In relation to the above observation and the problem statement, the study therefore aimed to investigate how smallholder farmers adapt to climate change using climate-compatible water management strategies.

In view of the research aim outlined above, the study's objectives were to:

i. Investigate and critically assess climate change-related opportunities and constraints for smallholder water management in Zimbabwe's Midlands and Masvingo provinces' drylands
ii. Critically examine the influence of local institutions' roles and capacity in enhancing climate-compatible water management among smallholder farmers in Zimbabwe's Midlands and Masvingo provinces' dry lands.
iii. Develop critical strategies that can be adopted to improve climate-compatible water management among smallholder farmers in Zimbabwe's Midlands and Masvingo provinces' dry lands.
iv. Use the key parameters that influence climate change compatibility for smallholder water management, as identified in the strategies, to develop a model that can influence a community of practice for smallholder farmers in Zimbabwe's drylands and beyond.

1.3 RESEARCH QUESTIONS

To attain the aim and above objectives, the following research questions guided the study process:

i. In what way(s) does climate change present opportunities and constraints for smallholder water management in Chiredzi and Zvishavane districts?
ii. In what way(s) do local institutions enhance or impede climate change compatible smallholder water management in Chiredzi and Zvishavane districts?
iii. Which strategies can be adopted to improve climate-compatible smallholder water management?
iv. What are the wider implications of the findings of this study in broader context of semi-arid and arid rural Zimbabwe?

1.4 THEORETICAL CONSIDERATION AND LITERATURE REVIEW

The IWRM framework informed this study's literature review as it feeds into the compatible climate development (CCD) concept. The two theoretical frameworks were identified as key in building resilience for vulnerable communities in dry lands. Resilience, in this study, refers to the systems' ability "*to anticipate, cushion, adapt, bounce back better and move forward from the effects of shocks and hazards in a manner that protects livelihoods and recovery gains and supports sustainable transformation*" (UNDP, 2015a). To ensure coordination within multisectoral water uses is achieved together with land and other resources integration, the GWP developed the IWRM framework (Global Water Partnership, 2000). On the other hand, the compatible climate development (CCD) concept was developed by Mitchell & Maxwell (2010). They linked development, mitigation and adaptation practices to ensure maximum benefits and reduce overlaps to achieve a more resilient future. Despite introducing the IWRM framework and CCD concept at different times in Zimbabwe, they both required stable institutional arrangements to reinforce each other in the water and other resources management.

Scholars (Ainembabazi, 2018; Bhaga et al., 2020; Brazier, 2018; Ofori et al., 2021) noted negative impacts of climate change pointing to the increasing number of regions, nations, communities and individuals whose livelihoods and resources base have succumbed and failed to adapt to the changes experienced. However, it is essential to note that scholars like Lal (2013), Attri et al. (2019) and IPCC (2022) argued that not all effects of climate change might be adverse to smallholder food and water resources. Climate change resulted in scenarios that are tapped as opportunities for smallholder farmers with the adaptation capacity (UN, 2017) and technology to harvest, store and manage water resources in extreme rainfall events that occur because of climate change like floods. These opportunities strengthen the community's climate resilience (IPCC, 2022a) in marginal rainfall areas where recurring droughts, and mid-season dry spells affect crop production.

Wittekind et al. (2016) revealed that in some cases, climate change has resulted in implementing effective irrigation systems and reduced the overdependence on rain-fed agriculture. However, this scenario was possible if communities had developed water harvesting structures and technologies. This pointed to a situation whereby smallholder water resources management followed resilience pathways. The pathways occur when sensitivity to climatic change can be reduced as opposed to the vulnerability pathways associated with climatic shocks and stresses that result when the system remains sensitive (UNDP, 2015a). Scholars, including Seo & Mendelsohn (2006), supported the same notion and added that due to climate change, communities might derive and enjoy benefits and opportunities that arise from increased costs of crops and livestock and fetch hire prices on competitive markets. This market-oriented argument did not receive substantial support and recognition in the context of poor and marginalized communities that do not have financial and technological backing to produce more cereals and livestock during droughts and flooding. It is argued that the scholars did not present clear evidence from marginalized smallholder farmers and these two notions apply mainly for the benefit of commercial farmers. Whilst the research targets the smallholder farmers who continue to suffer the burden of water scarcity, food insecurity and stagnation of agricultural economies are rising due to the changing climate. The study therefore, pointed the need for further investigation to reveal if any opportunities are at the disposal of smallholder farmers' water resources management, considering their social, environmental, and economic limitations towards climate resilience.

Most of the literature available supported by scientific evidence from projections (Unganai, 1996) and measurements (Mazvimavi, 2010), provided overwhelming and concurring evidence on the reality of climate change. Climate change impacts presented more challenges than opportunities for smallholder farmers' water resources, especially those living in fragile environments and marginal rainfall areas. Global warming resulted in erratic rainfall, increased intensity of floods, crop failure, frequency and severity of droughts, water scarcity becoming a perennial challenge, and loss of livestock and biodiversity. These reported cases are already threatening human livelihoods, especially in regions and communities with poor policies, ineffective response mechanisms and solid adaptation strategies. Mpandeli et al. (2015), GOZ (2015) and Brazier (2015) noted the significant increase in droughts since 1980 and a 5% reduction in the annual amount of precipitation over the last century as revealed by records starting in 1900. This affected the water balance of Zimbabwe and most sub-Saharan African countries (Rurinda, 2014).

A study by Rajeevan (2013) pointed that agroecological zones distribution were altered due to climate change. Climate change necessitated global warming, for example, Ethiopia recorded a warming trend, water scarcity, a shorter growing season for crops, and a further projected temperature increase of between 2 and 2.3 degrees Celsius, exposing the smallholder communities to droughts, increased water scarcity and food insecurity (Wittekind et al., 2016).

Climate change in Zimbabwe was experienced by reduced rainfall, poor distribution, and a temperature rise. These changes resulted in the shrinkage of agroecological zone II, which was the breadbasket of the nation and the expansion of the arid agroecological zone IV and V. The proportion of smallholder farmers living in dry lands areas significantly increased (Mugandani et al., 2012; Chikodzi et al., 2013; Government of Zimbabwe, 2015; Zimbabwe Resilience Building Fund, 2016). The shifting of agroecological zones due to poor rainfall, droughts and increase in atmospheric temperatures was further revealed by IFAD (2014) as the accelerator of ecosystem degradation. This rendered agriculture a riskier enterprise and a threatened livelihood option for under-resourced poor farmers. Smallholder farmers in drylands are the worst affected by climate change-induced water scarcity. Even though dry lands provide habitat and livelihoods to 34.7% of the world's population and cover 41.3% of the world's terrestrial area (UNCCD, 2017), poor smallholder farmers are the principal occupants of these areas, regardless of their lack of the required climate change coping strategies. This further points to the high degree of vulnerability for dry-lands inhabitants due to increased threats and fragility of the environment that is escalated by climate change.

Whilst IFAD (2014) supports climate change risk and vulnerability analysis, Rajeevan (2013) recommends high-level reviews that inform response strategy. Based on the existing literature, IFAD (2014) called for a better analysis of context-specific climate change-induced risk and vulnerabilities to deepen and broaden response strategies in line with resilience-building approaches. Based on the available literature, an in-depth assessment was carried out to reveal the missing voice of communities in drylands and present their experiences, cases and imaginations, taking advantage of their diversified contexts, which are not adequately revealed by literature.

Theorist, Douglass C. North in 1990 defined institutions simply as “rules of the game” (North, 1990). Furthermore, North (1990) opined that formal rules, informal norms and enforcement structure political, social and economic interactions are key in defining how the game should be played. Institutions in this case provide both incentive systems for the society and humanly devised constraints that provide operational framework (Ostrom, 1990, 2005). The study examined the existence and dynamics of different institutions and how these both constrained and offered opportunities to smallholder farmers’ water management as a climate change counter mechanism.

Different institutions offered structures that enabled the framework for extension services delivery by government, CBOs and NGOs, informal bodies, local authorities, local businesses, the private sector and pressure groups working at community levels (Crane, 2013). Literature identified the existence of formal and informal institutions, which evolved in response to water resources governance and reform, increasing water stress, conflicts and demand, all of which were climate change induced. It is worth noting that both global and national frameworks shaped most formal local institutions for water resources management (Mabiza, 2013). North (1990) & Ostrom (2005) further revealed that formal institutions exist in statutes, constitutions, regulations, and court systems/law that continue to offer guidelines for smallholder water resources management framework. The existence of informal institutions, including taboos, sanctions, customs, code of conduct and traditions enhances enforcement in line with the changing local context and culture. North (1990) further indicated that a blanket approach cannot be applied when dealing with institutions and their varied roles as the degree of effectiveness varies with local and changing context.

Zimbabwe's Water Act of 1998 Chapter 20:24 remained a key water management institution (GOZ, 1998). The Act provides operational framework to catchment and sub catchment councils through the ZINWA Act Chapter 20:25 (GOZ, 2002). The functionality of catchment and sub catchment councils promoted a catchment based management of water as enshrined in the ZINWA Act of 2002 (Government of Zimbabwe, 2002c). However, this did not solve the pressing water resources challenges faced by smallholder farmers.

The importance of local institutions was revealed by Crane (2013), who emphasized that local level institutions have greater influence to drive climate change mitigation and adaptation. This implied that their role in management of smallholder water resources cannot be underestimated. Furthermore, Wilk et al. (2013) noted that vulnerability is a matter of circumstances since climate change impacts are felt disproportionately to context specific political, institutional, economic and social structures where local institutions have influence. Local institutions' key roles in climate change and smallholder water resources management include governance support for local communities through training, policy, structural and resource support for multiple water users and stakeholders at grassroots level.

Local institutions led to the establishment of water resources user committees that help in portable and irrigation water management at grassroots level (Bowora et al., 2016). The local led management practice is an important sustainability strategy for most water related interventions (Swatuk, 2005; Wilk et al., 2013). Literature further revealed that local institutions provide a conduit for the transfer of external support to the affected communities (UNEP, 2012). Some communities have enjoyed sustainable access to water resources because local communities made significant investments in sourcing and linking communities in need of water infrastructure to investors and service providers. The United Nations Environmental Programme (UNEP, 2012) further stressed that local institutions play an important conflict resolution role and ensure equitable access and management of water resources, despite the growing pressure from multiple users and scarcity brought by climate change.

The study dug deeper and presented evidence of the existence of both formal and informal institutions, how they evolved, shaped by climate change, and offer water resources management for smallholder farmers from their varied cultural backgrounds, economic situations, and geographic contexts. However, it is critical to maintain the argument that, institutional roles may not be fully implemented and may not yield desirable results around a resilient community due to the top-down approach that evolved and shaped the institutions. Literature further indicated that context specific norms, traditions and culturally relevant practices were not documented as they evolved to guide the management of water resources in the changing climatic context.

1.5 METHODOLOGICAL CONSIDERATION

This section presents different methodological steps and procedures adopted by the study. Research methodology is commonly described as a systematic and theoretical approach to solve research problems (Kothari, 2004). The methodology section further highlights the philosophical positionality of the research. The Interpretivism philosophical positionality formed the foundation of this study (see next section). A mixed research approach was adopted, which informed the use of case study research design. The target population included chiefly the smallholder farmers in dry lands. A multi-stage sampling procedure including purposive and random sampling were used to select participants. Chapter three provides a detailed explanation of these methods.

1.5.1 PHILOSOPHICAL POSITIONALITY

Research philosophical positionality provides direction and roadmap to the research approach (Saunders et al., 2012). The philosophy provides guidance and the belief about how research data should be collected, analyzed, used in concluding, and applied in making key decisions. Through literature, the study noted that there has been so much focus on quantitatively driven climate change research that filled the knowledge gaps. Currently, climate change and scientific evidence from measurements and projections concur on public domains.

The research further stressed that scientifically deducted information lacks inductive backing that provides context specific data and scenarios required in problem solving, such as resilience building and adaptation by marginalized groups. Inductive approach was used as it generates a lot of indigenous knowledge systems (IKS), values, beliefs, traditional norms, impressions, perceptions, imaginations as well as lived experiences that natural sciences/objectivists will undoubtedly miss. It is critical to note that subjective indicators cannot be measured scientifically or objectively, rather they require inductive approaches.

In this study, an interpretivism approach was chosen, which according to Jackson (2013) helps to understand and work with different humans as social actors. The interpretivism approach was chosen in considering the differences in the context, regions, gender, cultural/traditions and age as diversified sources of information about climate compatible water management. This varied with different smallholder farming population groups from Mazvihwa community in Zvishavane to Save community in Chiredzi district. Chapter 3 discusses the philosophical position adopted in the study in detail.

1.5.2 RESEARCH DESIGN

This section presents research design, which according to Kothari (2004) and Pandey & Pandey (2015) sets the step by step procedure for systematically collecting, analysing and reporting the data. Qualitative research design dominated the study because of its interpretivism philosophy. Babbie (2011) indicated that qualitative design provides opportunities to describe relationships and events that may be missed by scientific approaches that rely on statistical tests. Qualitative design allowed the presentation of in-depth, openness and detailed study issues (Durrheim, 2006). The study was cross sectional in timing. The cross sectional approach allowed description of key incidences of the study phenomena within a given context (Saunders et al., 2012).

1.5.3 DATA SOURCES AND TOOLS

Empirical evidence was mainly collected from primary data sources. In addition, secondary data sources were used to triangulate and augment the empirical evidence. Fieldwork necessitates the collection of primary data, which is the data that is obtained as first hand from participants (Johnston, 2017). The primary data gathered by the study involved fieldwork and interviews. According to Kabir (2016) and Johnston (2017), secondary data is the data collected by other entities or individuals for their different primary use. In this study, secondary data included government reports and statistics, meteorological data from weather stations, national statistical reports, crop and livestock survey reports, maps, hydrological reports, local authorities' strategic plans, district profiles and development organization's reports, including those from community-based organizations.

To enhance the validity and reliability of the findings, the study employed mixed methods data collection approaches. Tools for primary data gathering used varied widely and remain guided by the study's research questions. Field observations, focus group discussions, transact walks, key informant interviews, and direct measurements were used to collect data. A questionnaire for smallholder farming households was the only quantitative data collection method employed to generate statistical information and measurements that helped triangulate and verify different information from other data sources.

1.5.4 DATA ANALYSIS

Quantitative data analysed include the data gathered by questionnaires and climate data collected from secondary source. The Statistical Package for Social Sciences (SPSS) version 16.0 was used for quantitative data analysis, with the Mann-Kendall Test (M-K test) XLSTAT 2021.3.1 (Addinsoft, 2022) employed for trend analysis related of climate data, including temperature and rainfall. The SPSS software was employed in the study because it analyses huge data, generates statistical presentations and analyses for different variables to provide descriptive statistics. The study employed M-K test for its merits in trend tests analysis especially when working with long term rainfall and temperature data.

Qualitative Data Analysis was conducted using a basket of techniques, including event/micro analysis, content analysis, phenomenology, and narrative analysis. Qualitative data analysis allowed the study to present case studies, pick significant events, identify emerging themes, and present lived experiences from the research participants as part of the finding on climate compatible smallholder water management. In line with the guidelines on qualitative data analysis, lived experiences, imaginations and memories from smallholder farmers' experience with climate change and water resources management were analysed and reformulated into a format readable and understood by the targeted research audience (Babbie, 2011).

1.6 SIGNIFICANCE OF THE STUDY

The research only included smallholder farmers from the selected Mazvihwa and Save communities where climate change impacts have presented limitations for smallholder water resources (FAO, 2019b; Hove et al., 2016). Data was collected from the smallholders using household questionnaires and focus group discussions. Key informants from local authorities, community leaders, traditional leaders, extension service providers, development partners and government departments were interviewed. The targeted communities and their respective participants were drawn from climatic or meteorological zone (region) III, a homogenous rainfall marginal area prone to droughts (Mugandani et al., 2012; World Food Programme, 2021).

The study targeted smallholder farmers in rural areas. It did not include urban farmers and peri-urban-based smallholder farmers due to the differences in livelihoods and coping strategies existing between the rural and the urban or peri-urban communities. Among smallholder farmers, groups A, B1 and B2 were included in the study, irrespective of their land tenure and affiliation to farmer groups or farmer organizations. Farmers categorized as large scale, newly resettled (A1 and A2) and those in group C were excluded from the study. Their exclusion was based on their absence in the study sites and their asset base and livelihoods, which differ from the targeted smallholder farmers in rural communities.

It was significant for the study to identify existing opportunities and gaps in water management for targeted smallholder farmers vulnerable to droughts. By identifying case studies and suggesting tools, strategies and frameworks for climate-compatible smallholder water resources management in dry lands, the study proposed new possible approaches that required rolling out to build the resilience of the communities in rainfall marginal areas. The study's findings provide advisories to the current and future smallholder farmers, farmer support organizations and institutions, researchers, administrators, and policymakers on resilience around smallholder water management strategies. The study is essential as it addresses smallholder water management and vulnerability in dryland areas.

1.7 SCOPE AND DELIMITATION OF THE STUDY

As noted earlier, the research's purpose was to assess climate change-compatible smallholder water management in the southern dry lands of Zimbabwe. Specifically, the study targeted the Mazvihwa and Save communities in the Zvishavane and Chiredzi districts of Zimbabwe, respectively (see Figure 3.1). The rationale for selecting these areas is that, when combined, Chiredzi and Zvishavane districts have diversified livelihood options that include dry land crop farming, livestock rearing, gardening and trade (World Food Programme, 2021). The targeted smallholder farmers in these dry areas have been experiencing increasing vulnerability to droughts and their coping strategies are declining. The study area witnessed the erosion of productive assets, where the vulnerability index remained higher than in other districts (Zimbabwe Resilience Building Fund, 2016).

1.8 ETHICAL CONSIDERATION

Ethics are philosophical guidelines that individuals are expected to observe in relation to the conduct and behaviour when dealing with other individuals, communities, businesses and societal norm (Akaranga & Makau, 2016). The University of the Witwatersrand Human Research Ethics Committee (Non-Medical) provides that research studies involving human participants should be guided by a key moral commitment to do no harm to the participants. Protecting privacy, wellbeing, informed consent, rights, vulnerability, confidentiality and anonymity of participants is key in ethical consideration (Akaranga & Makau, 2016). The study considered ethics seriously. The following were some of the ethical considerations imbedded and addressed in this study, as per the University of the Witwatersrand, Johannesburg:

a) Before any data collection exercise, ethical training and application for ethical clearance was done and approved by the Ethics Committee under Protocol Number: H20/08/18 (Annexure 1).

b) Informed consent was sought ensuring that the participants' consent was obtained freely. The participants signed an informed consent form (Annexures 10 to 15) after details of the study were provided. Other participants offered consent informally during the COVID-19 context.
c) Voluntary participation for the participants was a key element of ethics. The study provided full information to the participants and reaffirmed that participation was strictly voluntary. No respondent was forced or coerced to participate in the processes. The study further guaranteed voluntary withdrawal of the participants from the process at any given time and stage of the study.
d) Before the commencement of the study, it was imperative that the participants were made aware that if they felt uncomfortable, they were welcome to withdraw from answering any question. Permission and clearance by national COVID-19 taskforce was awarded to conduct research under COVID-19 context, with adherence to the national COVID-19 standard operation procedure and guidelines (Annexures 22 to 29). Wearing of face masks, conducting temperature screening, maintaining social distance and provision of hand sanitization to the community members who did not have the required personal protective equipment (PPE) was done before data collection.
e) Participant privacy and confidentiality were maintained and guaranteed at all stages of the research. No names and unique identifiers like national identity numbers were captured. Villages of origin and age were not shared with anyone. Pseudonyms were used to replace real names during the resulting and reporting of the research findings.

1.9 STRUCTURE OF THE THESIS

The structure of the thesis is divided into six chapters. The conceptualization of the research including research questions, objectives, scope and delineation as well as ethical considerations were delt with in Chapter One. Theoretical consideration and literature review chapter provides historical and contemporary striking views about the global, regional, and local discourse on climate change and smallholder water management. The gaps and new insights gained from the review of literature are presented as they inform the study. Chapter three outlines the methodological consideration, providing step by step procedure for the collection, analysis, and reporting research findings. Presentation of empirical evidence was done in chapter four, where the actual findings based on data analysis helped to answer the research questions. An analysis and discussion of the findings, together with the proposed model were outlined in chapter 5. The chapter provided an interrogation of the study finding in relation to existing knowledge and practices. Conclusions and recommendations drawn from the study findings and gaps were presented in chapter 6, providing pointers to future studies, influencing a community of practice and policy decisions. The following illustration presents the thesis outline (Figure 1.1)

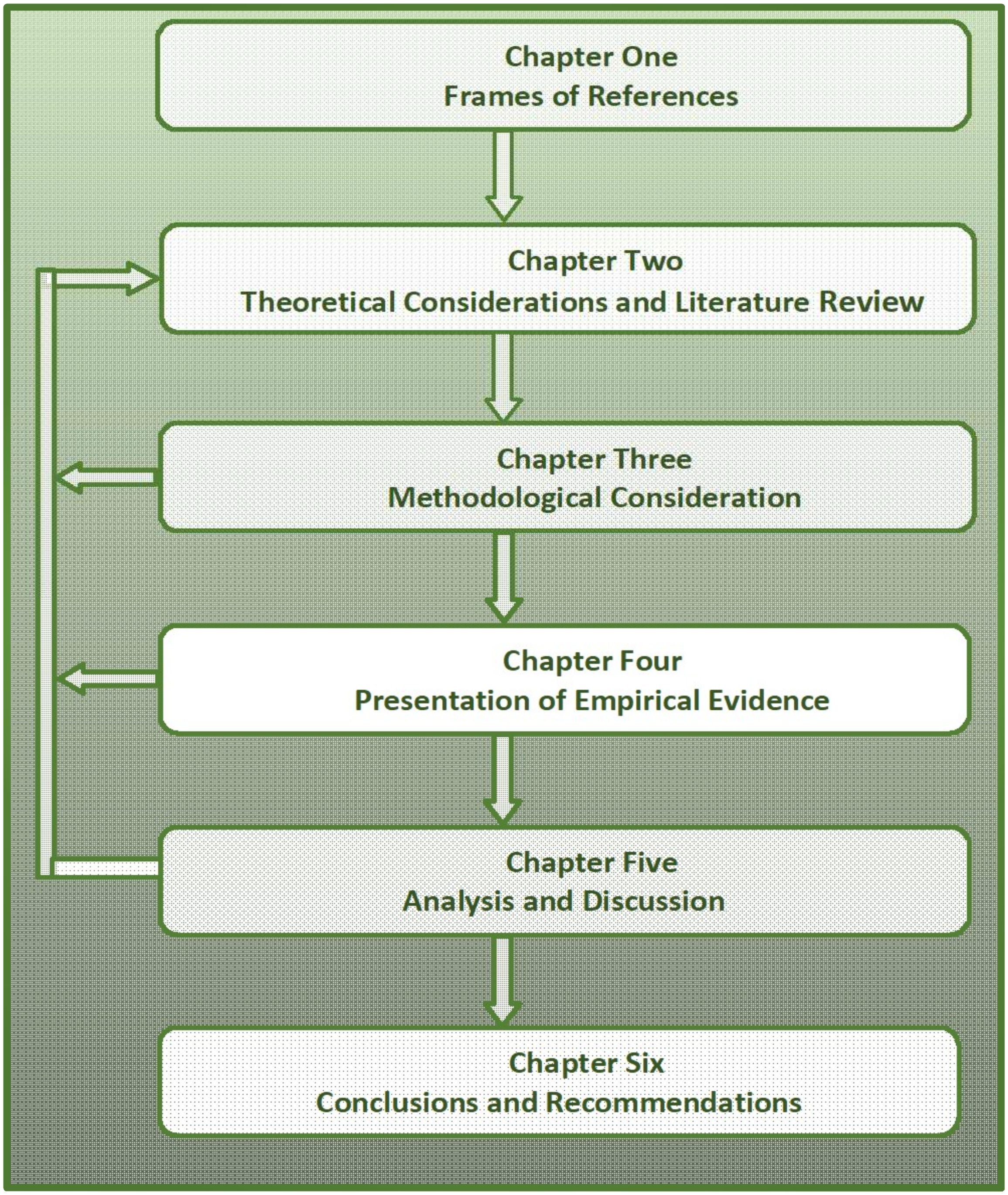

Figure 1.1 Structure of the thesis

CHAPTER TWO

THEORETICAL CONSIDERATIONS AND LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is dedicated to interrogating literature on historical and contemporary views on climate change and water management. Literature review is key in gathering the body of knowledge about the past and present views that inform the future of the research topic (Onwuegbuzie & Frels, 2016). Drawing experiences and attention from studies, conventions, commissions, events and discourse around climate change and water management, the study presented reviews that hold credibility from local to global scales. An in-depth literature review paid more attention to climate change in dry lands. The global overview within the climate change compatible thematic was presented. This chapter was arranged into seven main sections, starting with section 2.1, the introductory part. Section 2.2 has two subsections, 2.2.1 and 2.2.2, that discuss the theories and frameworks formed in the second section. The global discourse on the changing climate context and smallholder water was presented in the third section, 2.3, whilst the fourth section, 2.4, was dedicated to reviewing climate change and variability for smallholder farmers in dry areas. Literature on climate change and African smallholder farmers was reviewed under section 2.5. The sixth section, 2.6, reviewed local institutions' roles concerning the changing climate scenario and water management. Section 2.7 was dedicated to an overview of Zimbabwe’s climate change context, focusing on constraints, strategies, efforts, and gaps surrounding smallholder water resources management. Section 2.8 is presented as the concluding section.

2.2 THEORIES AND FRAMEWORKS ON CLIMATE CHANGE AND SMALLHOLDER WATER RESOURCES MANAGEMENT

The Integrated Water Resources Management (IWRM) and Climate Compatible Development (CCD) frameworks were selected as they provided anchorage to the study. The IWRM and CCD frameworks are explained in detail in the following sections.

2.2.1 INTEGRATED WATER RESOURCES MANAGEMENT (IWRM) FRAMEWORK

One of the theoretical frameworks that have been developed for the holistic management of water under the different shocks and stressors is the Integrated Water Resources Management (IWRM). The Global Water Partnership (2000) define the IWRM as “a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare equitably without compromising the sustainability of vital ecosystems.” IWRM was a widely and internationally accepted water management framework adopted by several countries to address the pressing global water-related challenges. The local community's participation in water resources governance including women's participation, was a fundamental principle. Tantoh & Simatele (2018) indicated the governance complexity that existed in Cameroon’s centralised water management framework, which undermined rural communities’ participation in water management and decision making. Water governance is defined by Global Water Partnership (2003) as “the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services at different levels of society.” Through decentralization of water resources management, the state was supposed to devolve certain functions and roles from the 1976 colonial Water Act, including issuing water rights (Gumbo, 2006). The definition of property rights, migration of water rights to water user permits issuance and assigning responsibilities to different stakeholders and institutions at the local level was discussed as the key priority IWRM solved (Mtisi & Nicol, 2003; Gumbo, 2006; Rogers & Hall, 2003).

Hassing et al. (2009) point out that IWRM (Figure 2.1) was designed and modelled from an “on-the-ground experience of practitioners." The review noted that several components of the IWRM framework have been in existence and in use dating back to the 1977 Mar del Plata Conference, which marked the first summit on water resources. The IWRM framework was propelled and became the “global bandwagon” after the Rio World Summit on Sustainable Development discourse of 1992 (Mapedza et al., 2016). The Rio Summit, also dubbed the Earth Summit, placed more emphasis on sustainable development, focusing on resource management, including water and its access by underserved population (UN, 1992).

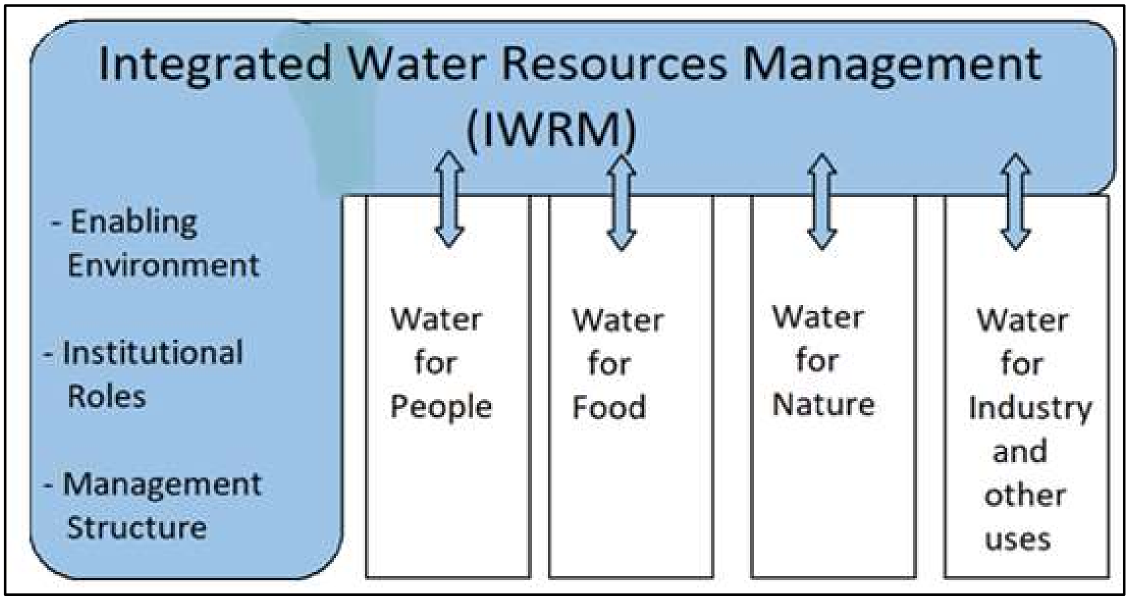

Figure 2.1 Integrated Water Resources Management Framework
***Source**: Global Water Partnership (2000) and Government of Zimbabwe (2012)*

The IWRM framework was an opportunity for countries struggling to balance the supply and demand side with conserving and developing water resources. Most countries, especially those from the developing world, including Zimbabwe and South Africa, were quick to adopt IWRM because its principles of economic efficiency, equity and environmental sustainability were promising to offer immediate solutions to the country's water challenges. Zimbabwe, therefore, became the first Southern African country to adopt IWRM (Manzungu & Derman, 2016). It was further noted that IWRM was introduced at an opportune time when Zimbabwe struggled to recover from the devastating drought of 1992 (Derman & Manzungu, 2017; Nangombe, 2015) and had no option and time to waste, hence the country had to domesticate the IWRM framework quickly.

Manzungu & Derman (2016) present a synopsis of Zimbabwe's water sector reforms dating back to 1890. It was a straightforward account that revealed the historical events and institutional setup within the sector. These were crucial influencers to the quick adoption of the imported IWRM framework. The country's 1976 colonial Water Act offered more preference to agricultural water use than other sectors by prioritizing the issuance of water rights to commercial farmers (Manzungu & Derman, 2016). According to Davis and Hirji (2014), agriculture under the control of around 4500 commercial farmers enjoyed a preferential and bulky water allocation compared to any other sectoral users. Eighty-two (82) percent, 15 percent and 3 percent of water resources were allocated respectively to agriculture, urban and industrial use, and mining operations (Government of Zimbabwe, 2012b).

According to Manzungu and Derman (2016) and Musemwa (2008), on gaining independence in 1980, Zimbabwe inherited colonial laws and policies, including the Water Act of 1976 and continued operating under its provisions till 1998. Under the 1976 Water Act and its provisions, it was difficult for the country to cope with the needs and aspirations of what people expected from independent Zimbabwe without reforming the Water Act and many other colonial laws. The 1976 Water Act was criticized for having many disadvantages affecting most of the country's population (Mukonavanhu et al., 2021). Between 1980 and 1998, at least 85 percent of Zimbabwe's water resources were controlled by around 4,500 white farmers who were holders of water rights in line with the 1976 Water Act that was operational (Manzungu & Derman, 2016). It was only after the Water Act of 1998 that replaced water rights with water permits; Chapter 20:24 was put in place, repealing the 1976 Water Act (Government of Zimbabwe, 1996; Mukonavanhu et al., 2021). Like the repealed 1976 Water Act (Government of Zimbabwe, 1996), the new act of 1998 ensured that all water remained vested in the state's interests (Government of Zimbabwe, 1998). As a result of the IWRM, the decentralization drive for water management in the Zimbabwean context was implemented through the establishment of ZINWA by the enactment of the ZINWA Act; Chapter 20:25 (Government of Zimbabwe, 2002c). The delineation of hydrological boundaries of Zimbabwe created a total of seven (7) catchment council areas and forty-seven (47) sub-catchment council areas. The move was meant to promote public and stakeholder participation in water resources governance at the local level (Government of Zimbabwe, 2012b).

As a provision for stakeholder participation, the membership of catchment and sub-catchment councils was based on the election of members and nomination procedures as set out in the ZINWA Act, Chapter 20:25 (Government of Zimbabwe, 2002c). In order to provide safeguards to the quality of water resources, the new Water Act, Chapter 20:24, was equipped with economic instruments, including the polluter pay principle (Government of Zimbabwe, 1998c). Other principles promoted by the IWRM include commercial water use or commodification (Mukonavanhu et al., 2021). The commodification of water was promoted and enforced through the user pay principle. According to Global Water Partnership (2000), the Dublin principle of valuing water as an economic good provided guidelines for water commodification. The IWRM's philosophy was guided by the fact that if users continued to view water as a free resource, as was the case in the 1976 water act as revealed by Mukonavanhu et al. (2021), its conservation, management and future development would be compromised. Therefore, nations will not escape from the impending global water crises.

Met with great expectation and hope as a means for achieving "…social equity, ecological integrity and economic efficiency", Zimbabwe, like many other countries, was quick in aligning its water management framework and institutional arrangements as predefined by the donor-driven IWRM (Derman & Manzungu, 2017; Mabiza, 2013a). According to Mabiza (2013), IWRM was embraced by Zimbabwe with the hope that it would result in economic, social and ecological advantages. Soon after the record-breaking and devastating drought of 1992, Zimbabwe was the first country in the Southern African region to adopt the IWRM framework. The country's water resources, the gross domestic product, the ecosystem and livelihoods were negatively impacted and were in a state that required serious resuscitation and recovery. According to Mapedza et al. (2016), the agricultural season's drought of 1991/92 was the worst in Zimbabwe's history, reducing the gross domestic product by 25 percent. The user pay principle in the water sector was countered and defeated by farmer unprofitability and the rising need for humanitarian assistance (Manzungu, 2011). Despite having adopted the IWRM framework, Mabiza (2013a) argues that IWRM did not yield the expected poverty reduction solutions since the causes of poverty were multifaceted, and it was too ambitious "to expect a single actor (water) to solve these problems alone."

Mabiza (2013) further argues that the IWRM's founding Dublin Principles that guided the commodification of water resources was a misplaced priority in the rural southern African context where poverty, economic decline and droughts are the order of the day. The study noted the application of IWRM as a generic approach being a weakness in applying foreign-driven reforms without adequate financial and institutional arrangements to fit into the local context. Furthermore, the principles of IWRM in Zimbabwe were not wholly beneficial because the central pillars, which are management instruments, enabling environment and institutional framework, were not fully developed and not fully functional. This was due to the development of the unforeseen socio-economic and political context around the country's land reform programme, which overshadowed the water sector reforms driven by IWRM (Mtisi & Nicol, 2003). The impacts of Zimbabwe's policies and programmes like the land reform proved some of the weaknesses of IWRM as it was affected and led to a stagnation phase due to donor flight between 2000 and 2009. As much as IWRM presented an opportunity for integrating all pillars in water management, it was clear that it was developed more on the theoretical than the practical application. A complex interdependence relationship between land and water was revealed by the exposed poor results in the first phase of IWRM implementation that was overshadowed by the land question (Manzungu & Derman, 2016). The water and land reformations were implemented at different periods, resulting in conflicting objectives and outcomes. Derman and Manzungu (2017) note fundamental changes in catchments, watershed areas and land ownership. The IWRM-led water sector reforms were stalled since land reform was one programme that attracted tremendous political, economic, and national interest. In addition, Feresu (2010) argues that IWRM implementation impediments and paralysis were also related to the massive fall of the agricultural economy. This political context evolved and diverted all the attention from water reforms, and the resultant country's isolation from the international scale resulted in "donor flights and funding decline."

The IWRM framework was further met with huge expectations from different players in the water sector. Davis and Hirji (2014), highlight that the imported IWRM was encountered by academics with expectations to provide a lasting solution to water resources management. The government's views and expectations from IWRM were that of economic development through expectation to derive significant economic growth and increased revenue flow opportunities from the commodification of water resources. The poor smallholder farmers expected improved access to water to improve their welfare and livelihoods since the constitution of Zimbabwe makes water access to every citizen a right (Global Water Partnership, 2015; Government of Zimbabwe, 2013a).

One of the critical challenges encountered when trying to domesticate the IWRM in Zimbabwe was the lack of women's participation, despite being one of the highly expected and promising Dublin Principles (Snellen & Schrevel, 2004; Global Water Partnership, 2011; Mapedza et al., 2016). Accordingly, Tagutanazvo et al. (2015) further stressed that although IWRM supported women's participation through informing decentralization of water governance, equity in women's representation in water management institutions was never achieved in both phases 1 and phase 2 of IWRM implementation.

In another study, Makurira and Viriri (2017) further reveal that despite Zimbabwe's stance on quick adoption of IWRM, the country's water resources development levels remained significantly low. The available water resources remained less than 30 percent, supported by the country's Mean Annual Run Off of 23,6 x 10^9 cubic metres. As a landlocked country, Zimbabwe's total area covered by water surface is only 3,910 square kilometres (1 percent) out of the total 390,580 square kilometres. With an increasing population of 1.1 percent annual growth rate (ZIMSTAT, 2012b), more pressure continued to be exerted on fragile water sector of the country. This portrays the water sector's fragility and vulnerability, whereby any slight alteration in the water balance has potentially catastrophic impacts on social, ecological, and economic development.

Zimbabwe's past inflationary pressures continued to suppress the IWRM developments. The historic economic inflation was reported to have grown from 100,000 percent in February 2008 to 231 million percent in July 2008. According to Mapedza et al. (2016), this greatly affected revenue generated from water by ZINWA. In 2008, the hyperinflationary pressures eroded financial value, resulting in difficulties and stagnation in the operation of the formed and decentralized institution, the Zimbabwe National Water Authority (Mapedza et al., 2016). The IWRM's underperformance and continued failure to meet stakeholder expectations remained in the spotlight and were subjected to different scholarly views. According to Mapedza et al. (2016), implementing IWRM-led water reform required supportive frameworks. The social, economic, and political context needed to be incorporated into the future. A competing political will, the underperformance of the economy, a decline in the agricultural sector, and energy crises were all key hindrances to implementing IWRM in Zimbabwe.

The IWRM framework in Zimbabwe entered its second resuscitation phase between 2011 and 2013. Significant developments in the second phase include support for the formation of the National Water Policy that came after the formation of the inclusive Government of National Unit (GNU) (Manzungu & Derman, 2016; Government of Zimbabwe, 2012). The second phase of IWRM witnessed a substantial financial injection by UNICEF in support of the IWRM. The support facility was conditional, barring other uses, including catchment councils and related decentralized institutions. The arrangement supported inter-ministerial coordination and the recovery phase in rural water supply and sanitation (Manzungu & Derman, 2016).

Literature revealed that some of the opportunities, including the devolution drive, can strengthen the decentralization of water resources management. IWRM can harmonize policies with overlapping competencies around the land, agriculture, water, and extractive industries. A set of legislative and policy frameworks are critical in water management. These include Zimbabwe's Water Act Chapter 20:24 (Government of Zimbabwe, 1998b), ZINWA ACT Chapter 20:25 (Government of Zimbabwe, 2002c), Rural District Councils Act Chapter 29:13 (Government of Zimbabwe, 2002a), Mines and Minerals Act Chapter 21:05 (Government of

Zimbabwe, 2012), Urbsan Councils Act Chapter 29:15 (Government of Zimbabwe, 2002b), Environmental Management Act Chapter 20:27 (Environmental Management Agency, 2005), and Public Health Act Chapter 15:09 (Government of Zimbabwe, 2018). Integrated Water Resources Management was viewed as an excellent opportunity for harmonizing these different legislation and policy provisions that could enhance the management and coordination of the water sector.

2.2.2 CLIMATE COMPATIBLE DEVELOPMENT (CCD) FRAMEWORK

Climate-Compatible Development (CCD) framework was developed to understand the nexus among climate change mitigation, adaptation and development. Mitchell and Maxwell (2010) present climate compatible development concept as a framework that created linkages and opportunities for triple win. After the realization that climate change has been threatening developing nations' human gains and related economic development, the concept of climate-compatible development (Figure 2.2) emerged as a proposed solution aimed at reducing competing approaches and the silo mentality around the climate triple win. Mitchell and Maxwell (2010) define CCD as "development that minimizes the harm caused by climate impacts while maximizing the many human development opportunities presented by low emissions, more resilient futures". The CCD concept sought solutions that minimize the threats and maximize the opportunities by creating sector-wide interlinkages. The CCD concept was accepted in southern Africa, including Zimbabwe (Stringer et al., 2013), as an applicable concept that may improve water management and other resources under the changing climate. In Zimbabwe, the CCD framework was adopted in the crafting of the National Climate Change Response Strategy (NCCRS) by the government (Government of Zimbabwe, 2015b)

Figure 2.2 Climate Compatible Development Framework
***Source**: Mitchell & Maxwell (2010)*

Some scholars applaud the climate compatible development (CCD) concept as a vehicle for responding to emerging complex development landscape risks, a set of some uncertainties and changing institutional, economic and climate patterns across the globe. Climate-compatible development brought realization and appreciation of the changing climate scenario. It is a multi-sectoral challenge that requires multiple and layered approaches, including vertical (national to grassroots) and horizontal (cross-sectoral) integration (Stringer et al., 2013). To achieve the concept's "triple wins", Stringer et al. (2013) indicates that national frameworks were directed towards synchronization to support cross-sectoral interventions. The case of Zimbabwe's inter-ministerial coordination of climate change issues proved to be an essential aspect of progression towards migrating of development and climate change approach to embracing CCD concept (Government of Zimbabwe, 2015b; Government of Zimbabwe, 2016b).

A critical analysis of the CCD concept indicated that Zimbabwe has something to count as the success of the concept. The linkages among development, mitigation and adaptation in this concept showed that any progress made in one pillar works to the advantage of reinforcing the other two pillars. According to Mitchell and Maxwell (2010), the achievement of low carbon emission was much anticipated due to the interaction of development interventions and climate mitigation strategies. On the other hand, a climate-resilient development emerged from development and adaptation interaction. Communities, however, anticipated some co-benefits from both mitigation and adaptation practices. The successes recorded, including the multi-stakeholder and the cross-sectoral approach, proved critical enablers for climate-compatible futures. The integrative nature of the framework enabled mitigation and adaptation efforts to yield tangible institutional, policy and practice benefits to the community of practice (Stringer et al., 2013).

Climate-compatible development remained a promising concept that helped countries, including Zimbabwe, influence structural, policy, institutional and economic arrangements for climate change. Stringer et al. (2013) highlights that climate-compatible development does not occur in a vacuum but requires linkages and superimposition with existing institutional arrangements to be effective. Capacity deficiencies within institutional arrangements were noted as barriers limiting the full adoption of the CCD concept (Stringer et al., 2013). Some gaps need further support to ensure that benefits can be realized and shared across various sectors and geographic locations. On the other hand, introducing the CCD concept to contexts with competing priorities was noted as a critical contributor to the failure of the CCD in addressing the intended issues.

2.2.3 LINKAGES AND APPLICATION OF INTEGRATED WATER RESOURCES MANAGEMENT FRAMEWORK AND CLIMATE COMPATIBLE DEVELOPMENT CONCEPT IN ZIMBABWE

The literature review indicates that the IWRM framework and CCD concept are foreign and internationally driven (Bickersteth, 2010; Derman & Manzungu, 2017; Manzungu & Derman, 2016; Mapedza et al., 2016; Stringer et al., 2013; Swatuk, 2005). This, however, should not be used as an argument and basis for discrediting these concepts. The IWRM framework and the CCD concept require serious sectoral and multi-level ownership from local scale to sub-national and national levels, where there is the interaction among practice, planning and decision. The critical discussion presented in this section argues from a standpoint of what was learnt and how practical the concepts and frameworks were in shaping climate-compatible smallholder water resources management in Zimbabwe and other developing countries.

Zimbabwe's drive towards decentralization through the enactment of the related policy was a foundation for successfully implementing the IWRM framework and CCD concept. Through the Devolution and Decentralization Policy (Government of Zimbabwe, 2020a), the government committed that "*there must be devolution of power and responsibilities to lower tiers of Government in Zimbabwe*." According to scholars including Jaspers (2014), Mapedza et al. (2016), and Mtisi & Nicol (2003), compatible climate development and integrated water resources management may produce better results under decentralized governance and resources management systems. The policy on decentralization and devolution in Zimbabwe was only enacted in the year 2020, more than a decade after the implementation of IWRM and CCD in the Zimbabwean context.

An analysis of different scholarly views on the Zimbabwean water sector revealed that IWRM addressed some foundational challenges around institutional arrangements, including policy formulation around water resources and water institutions. The IWRM addressed bedrock challenges that otherwise could render CCD ineffective. The two concepts reinforced each other in different time scales by allowing CCD to be layered effectively on the existing institutional arrangements whose formulation and IWRM influenced existence. Zimbabwe formed the National Action Committee (NAC) as well as National Coordination Unity (NCU), which are institutions responsible for overall inter-ministerial coordination to manage water sector developments which were identified by Stringer et al. (2013) as a critical structure required in the southern African context. Under the CCD, a Climate Change Office within the ministry responsible for the environment was formed. It is, however, critical to note that overall responsibilities do not sit in this office since climate change threatens multi-sectoral areas that require multi-level stakeholders and a multi-sectoral approach.

The CCD triggered new mechanisms, institutional arrangement, thinking and planning for coordinated and collaborative water resources management. This created space for testing stakeholder arrangements that had never worked together historically (Mitchell & Maxwell, 2010). Zimbabwe, therefore, took advantage of this space of practice to align sector-specific interventions in water and climate change through an inter-ministerial coordination mechanism. Several policies and frameworks in Zimbabwe were formed due to IWRM and

CCD. The IWRM led to the formation of the Water Act of 1998, ZINWA Act of 1998 and National Water Policy of 2013 (Government of Zimbabwe, 1998b, 2002c, 2012b). Climate compatible development (CCD), on the other hand, guided the formation of the National Climate Change Response Strategy (Government of Zimbabwe, 2015b) and National Climate Policy of 2017 (Government of Zimbabwe, 2017) and the guiding vision was that of "a climate resilient and low carbon Zimbabwe."

Despite all these achievements, the unsolved challenge remained in migrating the established policies to influence a community of practice (Stringer et al., 2017). Analysis from these developments indicated that Zimbabwe remained stuck with the transition from the policy to on-the-ground practices in some cases and took much longer than expected to realize the results from policy influence on the practical application of the integration of policy, development, and practices. Implementing the policies has been a great challenge due to the competing demands from the socio-political and economic context that structured national interests in Zimbabwe.

Although not fully developed, climate change funding started trickling into the national response strategy using Green Climate Fund and other facilities (World Food Programme, 2015). The climate financial mechanism is the mechanism that propels the triple wins mechanism promoted by the climate-compatible development concept.

2.3 GLOBAL VIEWS: CLIMATE CHANGE AND SMALLHOLDER WATER RESOURCES

World leaders, scholars and businesses concurred that the climate is changing due to global warming (Brazier, 2015; Government of Zimbabwe, 2017; UNCCD et al., 2009; IPCC, 2022; World Meteorological Organization, 2020). Climate change has resulted in extreme weather events and other drivers of food insufficiency and hunger crisis (World Food Programme, 2015). Climate change and the related impacts are reported to be rising sharply, exceeding the coping capacity and tolerance levels for both humans and the supportive ecosystems (UNCCD et al., 2009). Most of the world's regions have suffered from the impacts of climate change. Evidence from the world leaders' summit, COP26, indicates the existence of uneasy pressure among developed and developing nations. During his presentation at COP26, the President of Finland, Mr Niinistö, said:

"*As an arctic country, Finland is particularly concerned about the fast-warming Arctic region. Everyone else should be concerned, too: if we lose the Arctic, we lose the globe. In the Arctic, reducing black carbon and methane emissions is essential."* (Niinistö, 2021).

According to the UNCCD (2017), dry lands under the study refers to both arid and semi-arid areas that receive around 200 to 500 mm annual rainfall and are characterized by their high degree of low water availability. Only little and, or dry land species of vegetation survive in these areas (UNCCD et al., 2009). The measure of aridity that defines dry lands is the aridity index (AI). The index is a proportionate outcome of evapotranspiration achieved from the mean annual rainfall of an area (Davis & Hirji, 2014; UNCCD et al., 2009). Besides water, temperature was noted as a critical determinant of ecological interactions in dry lands. Temperature rise increased water scarcity issues and constrained smallholder farmers' livelihoods (UNCCD et al., 2009; FAO, 2018b; Filho et al., 2022). Smallholder farmers in marginal dryland areas have been highly dependent on the dry land ecosystems for survival (Amjath-Babu et al., 2016), and these ecosystems have been subjected to immense pressure and threats from climate change (UNCCD et al., 2009; USAID, 2019). Besides focusing on these past and current pressures, the study pointed out a gloomy future where water resources will continue to be a challenge affecting food production. Brazier (2018) and FAO (2018b) indicate that climate change would further present difficulties for smallholder farmers to cope with the changes and adapt their production in line with the changes.

There is an increase in the number of people, communities, nations, and regions whose livelihoods and water resources have been threatened by climate change (FAO, 2022; Shin et al., 2022; World Bank, 2019). The bulk of the reviewed literature presented the negative impacts of climate change. However, it is necessary to note that scholars, including Lal (2013), argue positively, indicating that some climate change effects may be beneficial to smallholder food and water resources. Climate change, in some cases, was attributed to increased rainfall, which is an opportunity for smallholder farmers with the capacity and technology for water harvesting. Wittekind et al. (2016) reveals that in some cases, climate change might result in implementing effective irrigation systems and reduce the overdependence on rain-fed agriculture. The study, therefore, calls for further investigation to reveal if there are more climate change opportunities at the disposal of the smallholder farmers in rainfall-marginal areas. The enquiry needs to consider water resources management practices under smallholder farmers' social, environmental, and economic limitations that have hindered smallholder farmers' potential adaptive capacity.

Literature reviewed presented debates on the definition of smallholder farmers. The most critical agreement within the debate on who constitutes the smallholder farmers is the concurrence that there is no widely accepted definition. It all depends on various factors, including the economic context and location of the farmers. Morton (2007) indicates that smallholder farmers cultivate small areas and use family labour in agriculture. Morton (2007) further presents views that smallholders are farmers who own small plots on which they grow crops on a subsistence basis and one to two cash crops whilst exclusively relying on family members for labour. These farmers are located primarily in marginal rural areas, where they encounter many limitations ranging from socio-economic, physical, and institutional barriers. Lack of productive assets, agricultural production, extension information (ZIMVAC, 2016, 2018, 2022), limited access to farmer's financial services, and lack of weather and climate information (Alidu et al., 2022; Meque et al., 2021). The identified challenges accounted for smallholder farmers' vulnerability in marginal and risk-prone areas (Morton, 2007; Chiriac & Naran, 2020; IFAD, 2020)

FAO (2012) further provides a widely encompassing definition that smallholder farmers "are small-scale farmers, pastoralists, forest keepers, fishers who manage areas varying from less than one hectare to ten hectares." Despite their significant contribution to economic growth, smallholder farmers occupy most of the degraded drylands and remote and marginalized areas (Donatti et al., 2019). Some of these marginalized and risky areas include valleys, flood plains, and reserves where land is fragile, water and infrastructure are exposed and threatened by climate and weather-related hazards, shocks (Amjath-Babu et al., 2016; UNDP, 2022), and other stressors. According to Donatti et al. (2019), an average of 75% of the world's farms are under smallholder farmers, the majority providing 60% of the agricultural workforce. Despite their climate and weather-driven vulnerability in agriculture and livelihoods (Liesdek, 2021), smallholder farmers produced around 80 percent of the food consumed in developing countries (UNEP, 2012; FAO, 2012). The world's smallholder farming context makes global food systems more vulnerable to the changing climate and extreme weather-related shocks since an estimated 75% of the world's food are produced by 12 plant species and only five animal species. (FAO, 2012). The smallholder farmers' heavy reliance on rainfed agriculture and rainfall-depended natural resources-based livelihoods further increased farmers' vulnerability (FAO, 2022; Donatti et al., 2019; Amjath-Babu et al., 2016). According to FAO (2012), a total of 1.5 billion poor people in developing countries out of 2.5 billion live in smallholder farming households.

Water is one of the resources that is threatened by climate change globally. Only 3% of the world's water is fresh, and 70% of this freshwater is committed to food production (UNCCD, 2014). According to Filho et al. (2022), water scarcity is an escalating global challenge, with management practices failing to cope with the increasing frequencies and magnitude of climate-induced shocks and stressors. FAO (2018a) indicates that if the world continues in the business-as-usual approach, the global water demand will exceed the supply by more than 40 percent by the year 2050, threatening 45 percent of the world's gross domestic product (GDP), 52 percent of world population, and 40 percent of cereal production.

The impacts of changing climate and variability were identified to be on the rise and threatening global food and income security (Rust & Rust, 2013); (Fanadzo et al., 2021; Meque et al., 2021; Quandt, 2021). The consequences of droughts alone accounted for 83 percent of damages and 30 percent of agricultural losses worldwide, which translated to USD29 billion (FAO, 2018c). Evidence indicates that around USD 96 billion was lost due to a decline in crop and livestock production (FAO, 2018c), partly linked to drought occurrences worldwide. FAO (2018c) further reveals that the African continent alone accounted for USD26 billion, Latin America USD22 billion, USD26 billion and Asia USD48 billion in the total losses incurred by the agriculture sector due to the impacts of the changing climate. According to World Meteorological Organization (2020), droughts alone accounted for 86 percent of the total livestock damage worldwide. Between 2008 and 2011, Kenya counted losses amounting to USD8.9 billion. Weather and climate disasters further explained the findings reported by the Government of Zimbabwe (2021) that revealed between 30% and 40% loss in livestock-based assets, and the World Meteorological Organization (2020) findings that around 90 percent of livestock losses worldwide were due to the impacts of droughts in the year 2016.

Climate change impacts on smallholder water affected a population reaching 22.2 million from the African continent. These were severely affected by the shortages of food in 2019 in the horn of Africa (World Food Programme, 2015). Ghana, for example, experienced reduced viability of smallholder agriculture for 70% of the population (Alidu et al., 2022) and South

Africa's most intensive drought-driven water shortages since the year 1904 (Bhaga et al., 2020; Fanadzo et al., 2021; UNDRR, 2021). The observed trajectory points that droughts would continue claiming dominance and wreaking havoc as a top climate-related hazard affecting vulnerable drylands, resulting in intensified water scarcity and reduced crop yields.

2.4 CLIMATE CHANGE IMPLICATIONS FOR SMALLHOLDER FARMERS' WATER AND AGRICULTURE IN AFRICAN DRYLANDS

Water has been a scarce resource in dryland areas. Various scholars, including Boko et al. (2007); Kurukulasuriya & Mendelsohn (2008), reveal that climate change intensified water scarcity worldwide. The ecosystems and biodiversity status of the drylands were primarily shaped by water scarcity and the related extremely unpredictable rainfall. Davies (2017) and UNCCD (2017) point to a case where the Zarqa basin, one of the arid areas in Jordan, has rainfall that averages 270mm per year but reaches the lowest 50mm per year and the maximum of 600mm per year depending on the seasonal performance. These high variabilities and low rainfall pointed to a vulnerable context within the dry land areas where most smallholder farmers reside. In 2011, a total of 184,000 Somalis were reported to have fled to other neighbouring countries due to devastating droughts in the predominantly dry areas of the horn of Africa (UN, 2013). Despite indications by the UNCCD (2017) on the importance of drylands as the resource base and critical life support service providers that produced about 44 percent of the world's crops, they continued facing extreme water challenges to support ecosystems, food production and economies of smallholder farmers. Around 20 percent and 70 percent of the drylands are used for crop and livestock production, respectively. Most drylands inhabited by smallholder farmers were identified to be located in rural communities where land degradation and water pressure are intense, making the land poor, unproductive and prone to degradation (UNCCD, 2017).

Climate change and variability-induced drought impact cascade throughout the dryland hydrological cycle, which poses high risks to water management in dry lands. The UNCCD (2017) note that climate change altered and accounted for the negative balances in water reservoir storage, groundwater resources, surface water flow and the available soil moisture. Apart from the documented impacts of the 1992/92 drought (Masih et al., 2014; Mpandeli et al., 2015; Nangombe, 2015), the significance of the 2015/16 droughts dominated the history of droughts in southern Africa and accounted for 66 percent decline in food crop production (Ainembabazi, 2018; Fanadzo et al., 2021; Frischen et al., 2020; UNDP, 2017; US Department of Commerce NOAA, 2018). The African continent was ranked highest and one of the most vulnerable regions with over 100 percent water stress compared to Europe with 8.3 percent and the world's average of 18 percent (FAO, 2018a). The vulnerability of dry lands is related to their physical and ecological context. Most drylands were degraded, reducing their water storage capacity since degraded landscapes and ecosystems have low water storage capacity. This, again, was cited as a critical challenge that exposed smallholder farmers to drought vulnerability in dryland areas (Davies, 2017).

The UNCCD (2015) highlights that drylands have been vital in providing goods and services, although they "evoke images of scarcity and harsh conditions." Out of the 576 Gigatonnes (Gt) of global biomass carbon, 83Gt (14 percent) is stored in drylands UNCCD (2015). The drylands have been vital carbon sinks and helped to reduce carbon emissions into the atmosphere, increasing global warming when released. Drylands are, therefore, critical regulators of the global climate system due to the amount of carbon they sequestrate.

Table 2.1 Dry land soils and carbon storage

Biomass Carbon (Gt)		**Soil Carbon**		
		All Soil C	**Soil Organic C**	**Soil Inorganic C**
Global	576	2,529	1,583	946
Drylands	83	1,347	431	916
Portion in Drylands	**14%**	**53%**	**27%**	**97%**

***Source**:* UNCCD (2015)

Drylands in the world are located in the global south, covering Africa, the Middle East, South America, Mexico and South East Asia. Roy (2018) indicates that the Global South is associated with political, social and economic instability, poor technological advancement, high rates of population and underdeveloped infrastructure. These characteristics all work as aggravating factors that magnify climate-related and other socio-economic vulnerabilities for dryland smallholder farmers who permanently live and depend on dryland ecosystems.

Due to global warming, a decline in cold days and increasing number of warmer days were noted over time (Aguilar et al., 2009**;** World Meteorological Organization, 2020). Evidence documented from the past studies, oral history, tree ring chronology analysis, lake sediments analysis, oral history, and prediction models points out that Africa was increasingly becoming more vulnerable and most threatened by intensified droughts (Masih et al., 2014; Masih et al., 2014; Rurinda, 2014; Fanadzo et al., 2021). Despite their vulnerable context, African smallholder farmers were identified as drivers of African economies and resilience (South Africa Department of Agriculture Forestry and Fisheries, 2012; Yegbemey & Egah, 2021**;** FAO, 2022)**.** Smallholder farmers occupy around 80% of farmland in southern Saharan Africa and Asian countries (FAO, 2012), making them a key population for consideration in Africa's socio-economic growth and stability. The analysis of climate change studies reveals that the African smallholder farming population were deeply rooted in poverty due to declining agricultural production (FAO, 2012; Government of Zimbabwe, 2021; World Bank, 2019).

Given the findings by Masih et al. (2014), drought occurrences in Africa between 1900 and 2013 resulted in more intensified impacts, increased frequency, high magnitude and expanded geographic scale. Masih et al. (2014) further point out that of the world record of 642 droughts in the same period (1900 and 2013), a total of 291 droughts translating to over 45 percent, occurred in Africa, thus making Africa a highly vulnerable continent. Some of the extreme droughts that were documented as continental still stand unique in the impact record. These include the 1972 to1973 seasonal drought, 1983 to 1984 and 1991 to 1992 that reduced smallholder farmers' agricultural economy (Frischen et al., 2020; Mazvimavi, 2010; Nangombe, 2015; The World Bank Group, 2021; UNDP, 2017).

The stories of African agriculture and smallholder farmers' vulnerability to the changing climate have been over-emphasized, with southern Africa (Quandt, 2021; Serdeczny et al., 2017) and Zimbabwe (Frischen et al., 2020; IFAD, 2021) recording increasing threats to food insecurity. Climate change resulted in the experienced record heat and water stress that shortened the growing period (Chiriac & Naran, 2020; IFAD, 2016; Maccarthy et al., 2021) and resulted in the declining trend of cereal yields by 27 to 32 percent (Abrams et al., 2017; Quandt, 2021; Maccarthy et al., 2021). According to Brazier (2018), Africa was heavily affected by climate change because of the location's vulnerability; lying between the tropics raised the vulnerability index of the population to droughts and other extremes**.** The affected African communities rely on their traditional livelihoods and coping mechanisms. UNCCD et al. (2009) indicate that marginal communities remain vulnerable to climate change. The noted reduced vulnerability existed since their coping mechanisms are ineffective and lacks ICT, technological support and future scenario required to build and strengthen their DRR capacity (Brausmann et al., 2021; Kumar et al., 2021; World Meteorological Organization, 2021; The World Bank Group, 2021). The impacts of these droughts resulted in a massive decline in agricultural production, with population exceeding 40 million in Africa facing starvation in the 2015/16 season (Meque et al., 2021), intensified water stress (FAO, 2018c, 2018a) and significant decline in the GDP (USAID, 2019; World Bank, 2019).

Regarding water management, the aggravating impact of climate change was identified as increasing since the proportion of people lacking water globally is also rising, with sub-Saharan reaching around 40 percent (SADC, 2016). All Southern African countries were identified to be battling water insecurities. The regional water storage capacity (Table 2.2) of Africa remained lower at currently 14% of the annual renewable water resources (ARWR) as compared to 70-90% storage capacity in developed countries and the 25% world average (SADC, 2016).

Table 2.2 Annual Renewable Water Resources (ARWR)

Sector	**SADC**	**African Continent**	**World Average**	**Developed World**
Water abstraction	170 M^3 per capita/year	251 M^3 per capita/year	570 M^3 per capita/year	1330 M^3 per capita/year
Surface water storage	14% ARWR	14%ARWR	25%ARWR	70-90%ARWR

Source*: SADC (2016)*

According to projections, African countries' risks were noted to surpass the risk of economically usable water resources before the advent of 2025. According to Roy (2018), the 2015 drought in South Africa negatively impacted water sources, affecting 2.7 million households (18 percent of the Kwazulu-Natal population).

Some of the intensive droughts have resulted in the forced migration of smallholder farming family members to better areas with opportunities and conditions. A documented case in Uganda, where pastoralists have migrated in search of drinking water for livestock which indicated that climate change-induced droughts threaten smallholder farmers' livelihoods (Mulinde et al., 2016 & UN, 2013). The region’s food and economic self-sufficiency were identified to be increasingly under threat, with 97% of sub-Saharan African economies being rainfed (FAO, 2022; Amjath-Babu et al., 2016; UN, 2022). This context further confirms the existence of a record undernourished population reaching 23 million in southern Africa between 2015 and 2018 (World Meteorological Organization, 2020).

2.5 LOCAL INSTITUTIONS AND WATER RESOURCES MANAGEMENT

Theorist Douglass C. North define institutions simply as "rules of the game". Formal rules, informal norms and enforcement structure political, social and economic interactions as alluded by North (1990). Furthermore, institutions help in defining how the game should be played. Institutions, in this case, provide both incentive systems for society and humanly devised constraints that provide operational frameworks (Ostrom, 1990, 2005). The study examines the existence and dynamics of different institutions and how these both constrain and offer opportunities to smallholder farmers' water management to counter climate change-related shocks and stresses and build community resilience.

Different institutions provide structures and the enabling framework for offering extension services by government, CBOs, and NGOs, informal bodies, local authorities, local businesses, the private sector and pressure groups working at community levels (Crane, 2013). The literature identified the existence of formal and informal (Musavengane et al., 2019), bureaucratic and community-based institutions (CCMT, 2014), which evolved in response to resource governance, including common pool resources like water and administrative requirements. According to CCMT (2014), formal and informal institutions, some managed through bureaucratic structures while others managed through local norms of trust and consensus, were identified to offer constraints for natural resources governance, including rural water. Some institutions responded directly to climate change induced water stress (Adom et al., 2022), conflicts and demand, all induced by climate change (Agrawal, 2008; Bowora et al., 2016; Crane, 2013).

It is worth noting that most formal and local water and climate services institutions were shaped by both global (Global Water Partnership, 2000, 2011) and national frameworks for water resources management (Government of Zimbabwe, 1998a, 2002; Derman & Manzungu, 2017; Hove et al., 2016; Mabiza, 2013) and climate change response mechanisms (Government of Zimbabwe, 2017, 2020b; Nangombe, 2015; Stringer et al., 2013). Views by North (1990) and Ostrom (2005) further concur that formal institutions exist in statutes, constitutions, regulations, and court systems/laws that continue to provide guidelines for water management framework. North (1990) further indicates that a blanket approach could not be applied when dealing with institutions and their varying roles because the degree of effectiveness varies with the local context. The existence of informal institutions, including taboos, sanctions, customs, codes of conduct and traditions, enhances enforcement in line with the changing local context and culture.

Literature identifies indigenous and local knowledge (ILK), also known as indigenous knowledge systems (IKS), as a key institution within the communities (Filho, Barbir, et al., 2022). The indigenous and local knowledge systems (ILK)[1] was deeply linked to indigenous and local practices by many African cultures and worked as an enabler for local climate adaptation. This institution suffered impediments, including a lack of sustainable documentation and knowledge transfer that continued to fade from generation to generation. Filho, Barbir et al. (2022) noted that the current transfer mechanism includes tradition and practice, which is fading away with the older generation.

Koehler et al. (2021) reveals that water management in rural Africa was implemented under different institutions and levels. Over 75% of the communal water points were managed using community-based approaches that offered risk sharing, management through consensus, trust, norms, local arrangements and local empowerment (Kativhu et al., 2018; Koehler et al., 2021; Bisung, 2021; Djono & Daniel, 2022). An average of 12% of water points in Africa were identified to be managed using bureaucratic systems within schools, religious organizations and health centres, and 14% were managed under an individualist approach (Koehler et al., 2021). Merits and demerits exist as water management is associated with different management practices. In Africa, the emergence of professional water maintenance services providers in the rural water supply was a huge promise for infrastructure sustainability (Koehler et al., 2021). The need for transitioning community-based water management into a more sustainable approach that cultivates ownership was noted. Kativhu et al. (2018) stress the need for addressing the training and skills gap and the absence of water point funds (Djono & Daniel, 2022) that are required to transition community-based management approaches into sustainable solutions for rural water resources.

[1] Indigenous and Local Knowledge Systems (ILKS) refers to "the wisdom, techniques, approaches, skills, practices, philosophies and uniqueness of knowledge within a given culture, developed by communities over the years through the accumulation of experience and experiments based on the understanding of local context" (Filho, Barbir, et al., 2022)

It was noted that institutions for climate services in the form of finance for adaptation, insurance and information gathering and dissemination were not fully developed (Alidu et al., 2022; Brausmann et al., 2021; Fanadzo et al., 2021; Meque et al., 2021; Yegbemey & Egah, 2021). According to FAO (2019) & Kumar et al. (2021), climate information drives planning and production in agriculture and water management. Nevertheless, an increase in hydroclimatic and meteorological disasters was noted with reversal impacts on developmental gains accumulated and protected by smallholder farming communities over decades.

Local institutions' critical roles in climate change and smallholder water resources management include governance support for local communities through training, policy support, and structural and resource support for multiple water users and stakeholders at grassroots level. The importance of these grassroots institutions was revealed by Crane (2013), who emphasizes that both vulnerability to the changes in climate as well as adaptation occur at grassroots level, where local institutions have influence. Therefore, their roles in smallholder water resources management cannot be underestimated. Furthermore, Wilk et al. (2013) note that vulnerability is a matter of circumstances since climate change impacts are felt disproportionately with context-specific political, institutional, economic and social structures where local institutions have more significant influence.

Regarding the Zimbabwean scenario, local institutions play pivotal roles in managing resources, including water. However, different governance systems present complementary, overlapping and sometimes conflicting roles (CCMT, 2014). Table 2.3 presents bureaucratic institutions common in Zimbabwe, while Table 2.4 presents assemblies and committees, all being key institutions that offered resource governance functions.

Table 2.3 Tripartite Governance Structure at Sub-National Level in Zimbabwe

Level	Traditional	Local Government	Central Government
District	Chief	Council	District Development Coordinator
Ward	Headman	Councillor	N/A (Not Applicable)
Village	Village Head	N/A (Not Applicable)	N/A (Not Applicable)

Source*: CCMT (2014)*

The existence and influential role played by the traditional leadership institutions represented by Chiefs, Headman and Village Heads as constituted by the Traditional Leaders Act

(Government of Zimbabwe, 1998a) was associated with the conservation and preservation role of water together with associated land resources. Despite being constituted under the Traditional Leaders Act, the traditional leadership institutions picked their roles from the Rural District Councils Act (Government of Zimbabwe, 2002a). This is one possible area of conflict that the study further assessed with regards to water management study areas. The local governance system provided for the Council and Councillors' existence as key institutions with critical roles in water management. The Councils were identified as a committee constituted by elected Councillors (CCMT, 2014), thus aligning the institutions with political offices and dictates of the period.

The research made deliberate efforts understand the political will and understanding of the same influence on climate-compatible water management. Therefore, the tripartite institutional arrangement was rated as key in enabling the environment and constraints in managing water resources in the changing, highly variable, and unpredictable climate context. Institutional arrangements were also identified as assemblies and committees at national, subnational and local tiers of government reaching village levels (CCMT, 2014; Government of Zimbabwe, 2020a). Table 2.4 presents the institutions as both assemblies and development arms that are existed in Zimbabwe.

Table 2.4 Assemblies and Committees

Level	Representative Assembly	Developmental Body	Chair of Developmental Body
National	National Assembly	District Development Fund	Director General
Provincial	Provincial Committee	Provincial Development Committee	Political Provincial Chair
District	Rural District Council	Rural District Development Council (RDDC)	District Development Coordinator
Ward	Ward Assembly	Ward Development Committee (WADCO)	Councillor
Village	Village Assembly	Village Development Committee (VIDCO)	Village Head

Source: CCMT (2014)

The existence of parallels, overlapping competencies, conflicting roles, and interests within the local level resource governance institutions, including RDDC, WADCO and VIDCOs, was noted by CCMT (2014) & Kurebwa (2018). The delegation of roles and sharing responsibilities are not fully exercised and understood as the system reaches the local community level.

Local water management institutions in Zimbabwe evolved from the pre-independence Water Act of the 1976 and the Water Act of 1998, Chapter 20:24 (Government of Zimbabwe, 1998c). The revised Water Act of 1998 provided powers and functions to catchment and sub-catchment councils. Sub-catchment councils provide area-specific planning and enforcement of legal frameworks that govern and coordinate multi-sectoral water use within the catchment and sub-catchment council. The catchment and sub-catchment councils' functionality promotes the catchment-based management of water resources as enshrined in the Zimbabwe National Water Authority Act of 2002, Chapter 20:25 (Government of Zimbabwe, 2002c).

Local institutions have established water resources user committees that help to manage portable and irrigation water resources at the grassroots level (Kativhu et al., 2018). Management of water at the community level by local institutions was identified as a critical sustainability strategy for most water management-related interventions. The literature further revealed that local institutions provide a conduit for the transfer of external support to the affected communities (UNEP, 2012). Some communities have enjoyed sustainable access to water resources because local communities made significant investments in sourcing and linking communities in need of water infrastructure to investors and service providers. The United Nations Environmental Programme (UNEP 2012) further stresses that local institutions play conflict resolution roles and ensure equitable access and management of water resources despite the growing pressure from multiple users and scarcity brought by climate change. The provision of information and standards within water management was identified to be a critical role for Provincial Water & Sanitation Sub-Committees (PWSSCs) and District Water & Sanitation Sub-Committee (DWSSCs) (Government of Zimbabwe, 2015c). Planning responsibility was also a complementary role of the Rural District Development Committee (RDDC) at the district level (Kativhu et al., 2018; Care International, 2017). The day-to-day management functions for community water points remained the key for the water point committees and village pump minders (Care International, 2017; IFAD, 2016; Mabiza, 2013; SADC-GMI, 2019).

Joshua et al. (2022) stresses that for the sustainability of local water management, resilient infrastructure and governance mechanisms were critical ingredients for achieving water security in the face of the changing climate. However, the study must argue that these roles may not be fully implemented and result in resilient communities due to the bureaucratic system (Koehler et al., 2021) that evolved and shaped most institutions. Literature highlights that context-specific norms, traditions, and culturally relevant practices were not documented as they evolved to guide the management of water resources in the changing climatic context. Therefore, based on these observations, the study dug deeper and provided evidence of the existence of both formal and informal institutions, how they evolved, shaped by climate change, and offer water management for smallholder farmers from diversified cultural backgrounds and contexts.

2.6 CLIMATE CHANGE, SMALLHOLDER FARMERS AND WATER RESOURCES MANAGEMENT IN ZIMBABWE

Zimbabwe has a sub-tropical climate characterized by only one seasonal rainfall that replenishes the country between October and March. (ZIMSTAT, 2016; Brazier, 2015; Zimstat, 2019). The country's annual average rainfall ranges from around 300mm with increasing patterns to slightly over 1000mm from the south and southwestern to the north and north-eastern, respectively (The World Bank Group, 2021; Red Cross Climate Centre, 2021). The Meteorological Services Department classifies Zimbabwe into three main meteorological regions defined by homogenous rainfall (Meteorological Services Department, 2018, 2020). The classification was divided into regions I, II and III (Figure 2.3 and Figure 2.4), with region I covering areas that receive the highest rainfall than the rest of the country on a long-term average, followed by regions II and III, respectively.

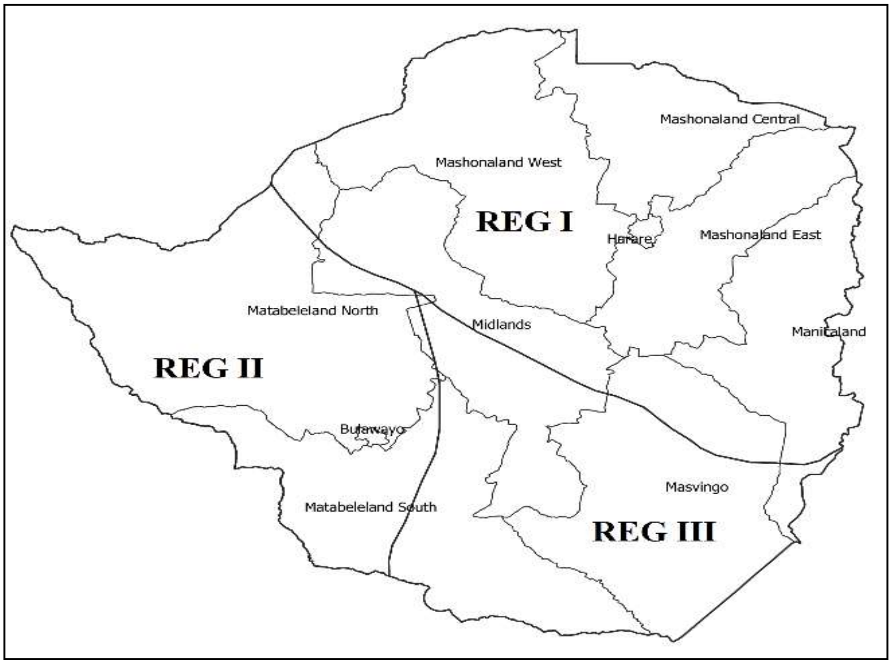

Figure 2.3 Zimbabwe's Homogenous Rainfall Zones
Source*: Meteorological Services Department (2020)*

The meteorological region I generally covers high rainfall areas in Manicaland Mashonaland provinces, while region II covers Matabeleland North and the northern parts of Midlands province. Region III covers the bulk of Masvingo, Matabeleland South and the southern parts of Midlands province. Rainfall averages were the determinant factor used to determine the meteorological regions. Every year, the Meteorological Services Department offers a seasonal outlook at the beginning of the rainfall season based on the expected forecast per region (Meteorological Services Department, 2020; Southern African Development Community, 2022). This offers farmers seasonal advisories on the performance of the season.

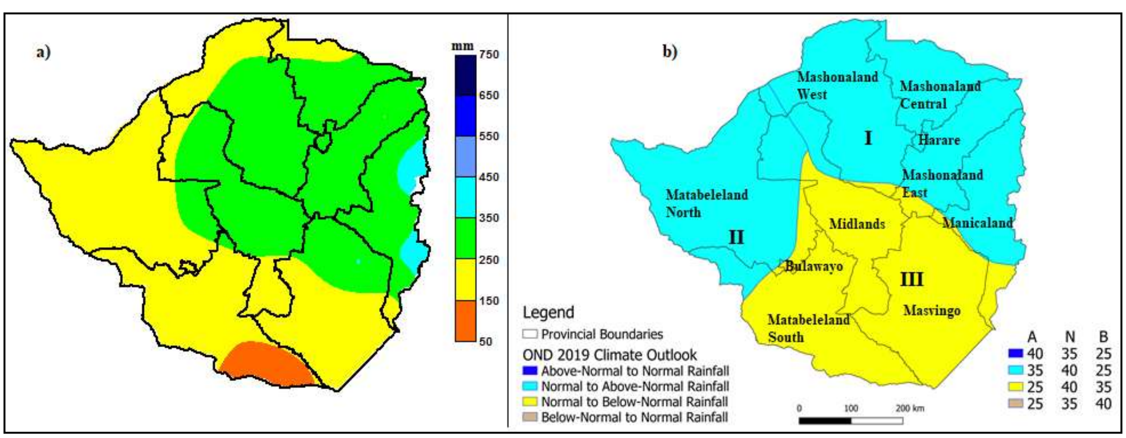

Figure 2.4 Zimbabwe (a) Long-term mean rainfall (b) Seasonal Outlook
Source*: Meteorological Services Department (2020)*

Zimbabwe has five agroecological regions (Figure 2.5) that are distinguished by rainfall, temperature, soils' agricultural productive potential and vegetation (ZIMSTAT, 2019). Agroecological zones (AEZ) are defined by FAO (1976) in terms of "climate, landform, soils and or land cover, and having a specific range of potential constraints for land use." The vulnerability of the smallholder farmers in Zimbabwe depends on the coping mechanism and the physical constraints of agroecological regions. Smallholder farmers' livelihoods in dry areas like Chiredzi and Zvishavane districts have been constrained by low rainfall and increased temperature.

Many scholars rank drought as the highest risk (Table 2.6) and a threat to Zimbabwe's agricultural economy (Brazier, 2018; Government of Zimbabwe, 2016a; Hove et al., 2016; Nangombe, 2015; SADRI, 2021; Wateraid, 2021; Frischen et al., 2020; Marambanyika et al., 2021; Welt Hunger Hilfe & Government of Zimbabwe, 2021). During the Presidential address to the Conference of Parties (COP) 26, Zimbabwean President (Mnangagwa, 2021), is quoted saying: "*Zimbabwe has not been spared from climate change challenges which have led to an increasing frequency of severe droughts and cyclone-induced floods."*

Drought occurrences in dry areas are more significant than rainfall events due to increased frequency. The El Nino Southern Oscillation (ENSO) has accounted for most of Zimbabwe's droughts (Kurukulasuriya & Mendelsohn, 2008). Cases of El Nino Southern Oscillation (ENSO) induced droughts in Zimbabwe are increasingly devastating (UNDP & GOZ, 2017; World Bank, 2019; ZIMVAC, 2016**;** Brazier, 2018; GOZ, 2016c)**.** According to the UNDP (2017) analysis, between 1970 and 2017, El Nino events resulted in 62 percent of droughts experienced in Zimbabwe in the years 1982/83, 1992, 2012, 2015/16 and 2019. Table 2.5 presents the rainfall amounts received in Zimbabwe under the ENSO's La Nina and El Nino scenario.

Table 2.5 Zimbabwe Rainfall Categories under different ENSO events (60 years)

ENSO Event	**ABOVE NORMAL**		**BELOW NORMAL**		**TOTAL**
	Number	Percentage	Number	Percentage	
El Nino	8	38 %	13	62 %	**21**
La Nina	10	67 %	5	33 %	**15**
Neutral	13	54 %	11	46 %	**24**
Total					**60**

Source*: (UNDP, 2017)*

Most of the El Nino events, with a proportion of 62%, were identified with below-normal rainfall that led to droughts in Zimbabwe (UNDP, 2017). Due to the increasing drought events, the staple food for Zimbabwe, maize was identified to be on a gradual decline in tonnes per hectare. Although the land reform program has increased Zimbabwe's area under crop cultivation between 2000 and 2016, yields continued to decline with negative contributions from the El Nino scenario. Zimbabwe experienced one of the strongest El Nino contexts that affected the 2015/2016 agricultural season (UNDP, 2017), leading to a decline in crop and livestock yields. According to the Government of Zimbabwe (2013b), between 1902 and 2005 alone, Zimbabwe recorded 43 droughts with different magnitudes. Nangombe (2015) noted a general 10-year cyclicity in the occurrence of devastating drought in Zimbabwe. Between 1983 and 2019, Zimbabwe was reported to have been hit by 22 record droughts, and eight significantly impacted livelihoods, ecosystems, and the national economy (Nangombe, 2015).

Table 2.6 Droughts in Zimbabwe 1950 – 2013

Grade	**Extreme**	**Severe**	**Mild**
Drought Years	1983, 1992	1967, 1968, 1982, 2004	1951, 1960, 1964, 1965, 1970, 1984, 1987, 1991, 1995, 2002, 2003, 2005, 2007, 2009, 2010
Total (Number)	2	4	16
Total (Proportion)	33%	6.7%	26.7%

***Source**: Nangombe (2015b)*

The impact of the 1992 drought in Zimbabwe resulted in the erosion and reversal of developmental gains and disruption of livelihoods. Evidence indicates that around 1 million cattle died of drought effects in Zimbabwe, and over 3 million people faced the risk of starvation (Government of Zimbabwe, 2013b, 2019b; Nangombe, 2015). In 2015, around 60% of the country's herd was reported to have succumbed to droughts (Government of Zimbabwe, 2019b). Low rainfall resulted in a drop in drinking water and fodder to support livestock. Table 2.7 shows the population in Zimbabwe affected by drought.

Table 2.7 Population affected by droughts at peak drought season.

Year	1986-87	1991-92	1994-95	2001-02	2004-05	2016-17	2018-19
Population	3 million	6 million	4 million	6 million	4.1 million	4.1 million	5.5 million

***Source**: Government of Zimbabwe (2019c)**;** UNOCHA (2013)**;** Nangombe (2015)*

According to the UNOCHA (2019), the 2018/19 devastating national drought pushed the country into a state of emergency. The overall aid basket required by the appeal amounted to

USD464 million, with Midlands and Masvingo provinces recording a total of 1.1 million people affected by food shortages.

According to the Government of Zimbabwe (2016c) and Frischen et al. (2020), decadal and interdecadal changes in rainfall increased drought frequency. The scenario was tracked in the period from 1915-1916, 1921-1922, 1923-1924, 1946-1947, 1967-1968, 1972-1973, 1982-1983, 1986-1987, 1991-1992, 1993-1995, 2002-2003, 2011-2012, 2015-2016 up to 2018-2019. These climate change and variability-related shifts resulted in devastating impacts on the southern region of Zimbabwe and varying intensity and spatial extent at the national scale (Frischen et al., 2020). Between 1982 and the year 2020, the International Federation of Red Crescent (IFRC) recorded a total of 38 weather and climate-related operations to provide relief to the affected communities (Red Cross Climate Centre, 2021). Zimbabwe incurred a recorded loss of around USD126 million per annum due to climate-induced production risks (World Bank, 2019), translating to a 7.3 percent loss in agricultural GDP. Droughts intensified poverty prevalence and vulnerability among smallholder farmers in Zimbabwe (World Bank, 2019), where the management of agricultural climate-related risk capacity is not fully developed (Arce, 2016).

Brazier (2015) notes a trend that revealed that between 1900 to 2010, Zimbabwe experienced an increase in temperature by 0.4 degrees Celsius. A debate on the decrease in rainfall was not statistically significant from 1955 to 2003 (Mazvimavi, 2010). A 6 percent increase in the 1970s, a 5 percent declining trend in the 1980s (Nicholson, 2000), and an overall decrease of 5 percent since 1900 pointed out the intra-seasonal and inter-seasonal precipitation variability (Brazier, 2015)**.** Current crop failures, the declining stocks of surface water resources, and the associated groundwater recharge decline of 30-70 percent in the western parts of the country (Brazier, 2015) were noted as some of the climate change and variability manifestations in Zimbabwe. According to Davis & Hirji (2014), around 70 percent of the Zimbabwean population that lives in rural mining and tourism sectors rely on groundwater resources. Groundwater resources were therefore identified to be playing a contributory role to the socio-economic development of Zimbabwe (Amjath-Babu et al., 2016; Macdonald & Edmunds, 2014; Nijsten et al., 2018; Rural Water Supply Network (RWSN), 2021).

Despite contributing very little to global emissions, Zimbabwe and Africa are hard hit by climate change (Behnassi et al., 2018). This view was further reinforced by the Zimbabwean

President's address to the 26th Session of the Conference of Parties (COP26), who commented that: *"It is most unfortunate that the impact of climate change is disproportionately borne by the vulnerable communities, which have contributed the least to the current stock of atmospheric carbon."* (Mnangagwa, 2021)

Zimbabwe has witnessed the changing climate scenario and variability-induced seasonal changes in rainfall and temperature surges associated with early cessation, mid-season droughts and violent storms in some regions, including Masvingo province (Rurinda, 2014). Climate change related impacts on the agroecosystems further burdened smallholders and aggravated the food security situation in Zimbabwe. These climate-induced agroecosystem changes and resource availability indicated the need for reclassification of the natural regions (Figure 2.5a), which was overdue (Chikodzi et al., 2013; Mugandani et al., 2012). The Mugandani et al. (2012) reclassification used 36 years old climatic data (1972 to 2006). The results determined the new classes with agroecological zones (Figure 2.5b).

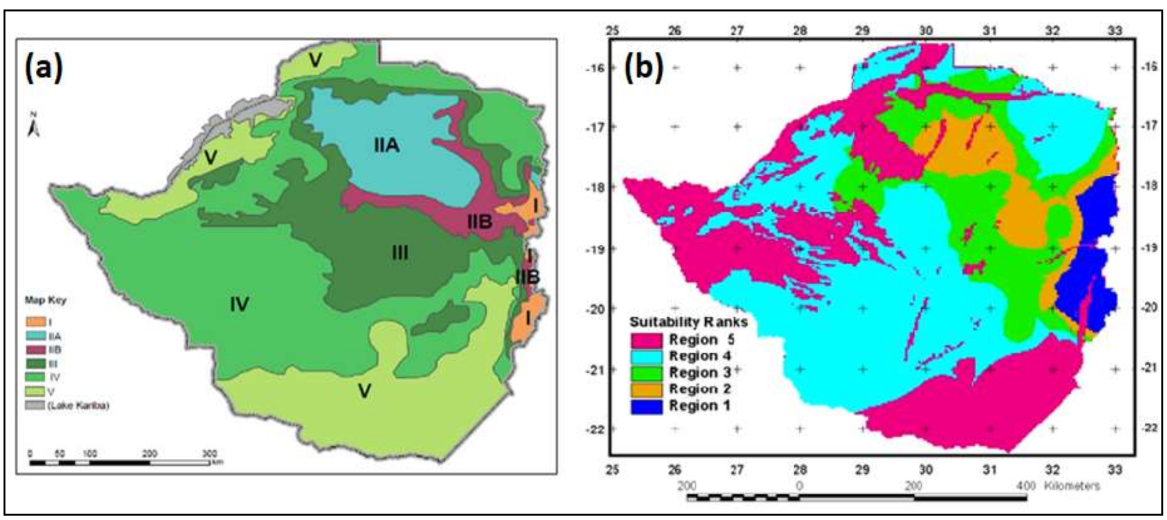

Figure 2.5 (a) Zimbabwe's old agroecological region (b) New agroecological region map
***Source**: (a) Vincent & Thomas (1960); (b) Mugandani et al. (2012)*

Figures 2.5 (a) and (b) resented the old and newly revised agroecological regions. The old AEZ classifications were done by Vincent & Thomas (1960), while the newly revised ones were carried out by Mugandani et al. (2012). Notable changes of the old 1963 natural regions was based on the expansion and shrinkage of some zones from the old classification compared to the new one. Table 2.8 presented the characteristics, sizes and noted changes of the AEZ.

The changes noted in the AEZ implied that more climate change and water-related vulnerabilities were affecting communities' capacity and limiting their potential to produce enough food and collect sufficient water for sustenance throughout the year. Over 65% of Zimbabwe's land surface is covered by drylands and occupied by ecological regions four and five (ZIMSTAT, 2019). A proportion reaching over 60% were identified as inhabitants of these dryland rural areas where smallholder farmers have developed a basket of coping strategies (IFAD, 2016).

Table 2.8 Changes in agroecological regions

Natural Region	Size (Proportion)			Comment
	Old (b)	New (a)	Change	
I	1.8%	4%	106%	Shifted towards the western side of the country.
II	15%	7.6%	49.3%	Region II encroached into region III (especially Mhondoro district).
III	18.7%	16.1%	13.9%	Part of natural region III encroached region IV.
IV	37.8%	39.9%	5.6%	Gweru was downgraded from region III to IV, and Hwange was downgraded from region IV to region V.
V	26.7%	32.5%	22.5%	The greater part of Hwange increased to region V.

***Source**: Mugandani et al. (2012)*

Rainfall is critical for Zimbabwe's climate (Brazier, 2015) and water balance (FAO, 2019b). Being a landlocked country that depends on one seasonal rainfall, Zimbabwe's agriculturally based economy responds to changes in water balance as detected by rainfall. In some areas, rainfall has proved to impact directly on the availability of groundwater (Macdonald & Edmunds, 2014; SADC-GMI, 2019). In agroecological regions IV and V, smallholder farmers have developed livelihood coping strategies, including extensive and semi-extensive farming, benefiting from average annual precipitation ranges of between 450-600mm and below 450mm in a normal rainfall season, respectively (ZIMSTAT, 2019).

According to Brazier (2018) and the Government of Zimbabwe (2016c), the shrinkages and expansion of some agroecological zones responded to the experienced rainfall variability and the noted general temperature increase that resulted in the 0.4 degrees Celsius rise since the year 1900. This further explained the slightly warmer winter records that started after the 1980s and record-breaking surface temperature warming that the Government of Zimbabwe (2015a) further cites as the reason behind the increased number of hot days and nights.

IFAD (2020) reveals that Zimbabwe has around 1.3 million smallholder farmers who occupy around 70 percent of the country's agricultural land. Smallholder farmers derive their livelihoods from less than 2 hectares of land per household. Smallholder farmers were categorized as A, B1, B2 and C groups. Category A defined the poorest households with limited land and labour. Humanitarian and other social safety net programmes target this group of smallholder farmers. Zimbabwe has a total of 107,408 farmers under this category (IFAD, 2016), which is approximately 7 percent of the total number of smallholder farmers. Smallholder farmers reaching 322,223 (approximately 21%) rural smallholder households were categorized under B1. They are poor households with land and labour, although they lack financial resources. If supported, this group of smallholder farmers can transition from poverty, food and income insecurity and increase food production. Most smallholder farmers (approximately 58%) are in category B2, which reached 889,949 smallholder farmers with both access to land and labour, although they face financial limitations. Category C, which is approximately 14% (214,815) of smallholder farmers, define the smallholder farmers with land and labour, although they lack access to credits. The Government of Zimbabwe (2021) notes a considerable decline in smallholder farmers' savings and productive assets, ranging from 30 to 40 percent, due to climate and weather-related livelihood hazards and stressors.

In addition to climate change, some critical challenges that are faced by communal smallholders include shortage of inputs, lack of financial support, and unavailability of climate and weather-related insurances. Efforts for smallholder subsistence farmers to cope with crop pests, animal diseases, and land degradation are lacking, and these issues continue to work as aggravating factors against marginalized farmers.

2.7 STRATEGIES, EFFORTS AND GAPS IN CLIMATE CHANGE AND SMALLHOLDER WATER RESOURCES IN ZIMBABWE

Various efforts and strategies were implemented in response to the changing climate in Zimbabwe. For example, drought relief food deficit mitigation (Government of Zimbabwe, 2016a), agricultural weather-indexed insurance (Arce, 2016) and livestock feeding programmes (Government of Zimbabwe, 2019b). Changes in climate helped to develop, strengthen and shape different institutions and institutional arrangements. Climate change was critical in determining policy direction in Zimbabwe (Kashangura, 2014). To reduce smallholder farmers' vulnerability to hunger, the Zimbabwe government built the national grain reserves that the country was supposed to depend on during the droughts (Government of Zimbabwe, 2018, 2021a; World Food Programme, 2015). Despite these efforts made under different national and international development frameworks as well as resilience and humanitarian responses, grain reserves were not successfully built over the past three decades. The grain reserve efforts failed to cushion the country's population against climate change-induced droughts. Consequently, Zimbabwe became an aid-dependent and cereal net importing country to ensure the country was well fed. Food insecurity in Zimbabwe has seen rural and urban populations receiving various aid and humanitarian baskets, including social cash transfers.

Several policies and frameworks including National Climate Policy (Government of Zimbabwe, 2017), National Adaptation Plan (Government of Zimbabwe, 2019a) and climate smart agricultural frameworks (CIAT & World Bank, 2017; Sibanda et al., 2017) were put in place to support community climate actions. Through the enaction of the Zimbabwe Climate Policy of 2016, the government of Zimbabwe deliberately ensured that adaptation was made a national priority (Government of Zimbabwe, 2016c). The Zimbabwe Climate Policy provides guidelines for implementing the National Climate Change Response Strategy (NCCRS) (Government of Zimbabwe, 2015b). Further national commitment to the Paris Agreement (Government of Zimbabwe, 2021b) indicated Zimbabwe decarbonization strategy (Government of Zimbabwe, 2015a). The Government of Zimbabwe (2019a) further commits that instead of focusing on adaptation, most resources were spent on providing crisis modifier mechanisms and humanitarian support due to increased climatic-borne humanitarian needs.

Various efforts including improving water governance, participation of users, research and awareness were made to reform the Zimbabwean water sector (Government of Zimbabwe, 2012b; Hove et al., 2016; Makurira & Viriri, 2017; Manzungu & Derman, 2016; Mtisi, 2011; Swatuk, 2005). Findings by Mtisi (2011) further reveal that the reformation of the country's water sector was modelled in response to the growing demand for water to balance the needs of a growing population and industrial and agricultural consumption levels. From precolonial to colonial and post-independent Zimbabwe, water attracted various management instruments and institutional arrangements. The 1913 Water Ordinance (Mtisi, 2011) was a typical example of colonial management of agricultural water together with the repealed 1927 water act and 1976. After the adoption of the IWRM (Global Water Partnership, 2000), the 1998 Zimbabwe Water Act Chapter 20:24 (Government of Zimbabwe, 1998c) repealed the 1976 Water Act

Chapter 20:22 (Government of Zimbabwe, 1996). It addressed the access, control, use and privatization of water by a few elites. The new arrangement where water ownership and control were vested in the state was a huge commitment to ensuring equity in water resource development, allocation, and use. Policy commitments and developments ensured that institutions were established as necessary vehicles for driving the water development, management, and governance agenda.

The sub-Saharan African region depicts a future where climate change-induced water stress, food insecurity and disasters continue to reinforce each other. Some climate change strategies lack investment and political will, making the country's water and smallholder farmers vulnerable to climate change. A general vulnerability was high in low rainfall areas. Zimbabwe’s mean annual precipitation was identified to vary significantly from one region to the other, with the southern parts of the country receiving less rainfall averaging around 337 mm per year in Beitbridge and Chiredzi belt. A gradual increase of rainfall towards the northeast, reaching the side of the country reaching 1110mm per year in the Eastern Highlands (Davis & Hirji, 2014), indicate that Zimbabwe's rainfall is also controlled by relief (ZIMSTAT, 2016a). Various studies reveal that groundwater information and monitoring capacity was a huge gap that policy, research and development are urged to consider (Davis & Hirji, 2014). Zimbabwe relied on the National Water Master Plan developed by InterConsult in 1986, which indicated groundwater development potential and subdivided Zimbabwe into ten major hydro-geological units. The outdated hydro-geological information available for Zimbabwe is outdated and requires revision (Pavelic et al., 2012) since adaptation and mitigation depend on a complete set of historical and updated information.

Institutional and practice gaps remain despite Zimbabwe having made many local, regional, and international commitments to the development of the water sector. These commitments range from the UNFCCC convention in 1992, Ramsar Convention on Wetlands conservation, the NCCRS framework, ZINWA Act, National Water Policy, and Climate Policy, among other supportive frameworks. Lack of political will and commitment to resources were identified as critical areas that affected the effectiveness and capacity of institutions in addressing climate change and smallholder farmers' water management.

With at least 70 percent of the country being dependent on groundwater, groundwater productivity also depends on annual precipitation. This cyclic nature and the nexus in need for water resources management may present a gloomy future since rainfall is no longer predictable, whilst the current groundwater stock information is unknown (Davis & Hirji, 2014). Literature points out the existing climate and weather-related risk management gaps. The insurance models and products identified can be referred to as work under progress due to failure in the pretesting period to provide sustainable cover to smallholders and offer commercial viability to service providers. The low uptake of Econet's EcoSeed cover and the withdrawal of services by ZimNat Lion insurance after a pilot year are vital examples of a long journey ahead (Arce, 2016).

2.8 GAPS IN KNOWLEDGE

Zimbabwe's vulnerability (Government of Zimbabwe, 2021b), poverty (The World Bank Group, 2020; World Food Programme, 2022), high rate of population growth, inadequate water resources (FAO, 2019b; Hove et al., 2016), heavy reliance on rain-fed livelihoods (Frischen et al., 2020; IFC - World Bank Group, 2022), weak and inadequate early warning systems (Government of Zimbabwe, 2021b; FAO, 2019b; UNDP & Government of Zimbabwe, 2017) continue presenting new challenges. Based on the increasing multifaceted and multi-dimensional nature of climate shocks and hazards, there is confusion on the existing opportunities and constraints brought by climate change and what outweighs the other. It is still unclear whether there is a need for communities to celebrate the so called "climate change opportunities" because of the growing context and discussions around maladaptation (Barnett & O'Neill, 2010). The concept of maladaptation further creates a huge knowledge gap and doubts on the suitability and appropriateness of different strategies that can be adopted in climate compatible water management practices for smallholder farmers. It is currently not clear whether the existing local institutional arrangements for water management (Derman & Manzungu, 2017; Swatuk, 2005) and climate change (Government of Zimbabwe, 2015b) at grassroots, sub-national, national, and international levels are positioned to build climate resilience for communities in rainfall marginal areas. The study's objectives dwell much on these knowledge and practice gaps and aim to provide the much-needed contribution to the body of knowledge and a community of practice.

CHAPTER THREE

METHODOLOGICAL CONSIDERATIONS

3.1 INTRODUCTION

The methodological consideration chapter focuses on the research philosophy, design and methodology and methods for gathering and analysing data. Kothari (2004) highlights that research methodology refers to a systematic and theoretical means of solving research problems. This methodology section covered the first part, the introductory part of the chapter, followed by the philosophical positionality or the research approach. This section presents different methodological steps adopted to discover knowledge and provide information that answers the research questions outlined. Finally, the research design section, which covered the most significant part of the chapter, under the research design section, detailed the description of study sites, the target population with sampling procedure, data instrumentation, data analysis and a methodological reflection section. The following sections detail the research methodology considering the stages presented in this introduction.

3.2 PHILOSOPHICAL POSITIONALITY (RESEARCH APPROACH)

Research philosophy, according to Easterby-Smith et al. (2015) provides contextual analysis of the research setting that gives meaning to the study. It also gives a clear articulation of various assumption that provide influence on researcher’s choices in selecting study design. The philosophy plays key role in the understanding of the relationship that exist between research data and different theoretical grounding. Saunders et al. (2012) observed that the philosophical positionality provides direction to the research processes. Furthermore, scholars, including Lapan et al. (2012), suggest that philosophical positionality guides the research design and assists research in understanding the belief behind the research data collection process and interpretation. Therefore, a clearly defined research philosophy guides how research data should be collected, analysed, and used in concluding and decision-making.

Literature revealed that there has been so much focus on quantitatively driven climate change research that filled the knowledge gaps. This study was designed to contribute to the socio-economic dimension of climate change concerning smallholder farmers' water resources management in dry areas. Various scholars gathered more scientific evidence on climate change and variability in Zimbabwe. These are from different academic fields, including agriculture, political science, economic development, soil science, water resources, environmental management and ecology, including Unganai (1996), Mazvimavi (2010), Mugandani et al. (2012), Chikodzi (2013), Manyeruke et al. (2013), Nangombe (2015), UNDP (2017), Brazier (2018), and Marambanyika et al. (2021). Therefore, this study acknowledges that the context-specific socio-economic dimension of climate change continued evolving and changing based on the community's response mechanism. While planners must draw references from scientific projections and statistical models, it is in public domains that climate is changing and scientific evidence from measurements and projections concur with each other.

It is critical to note that subjective indicators cannot be measured scientifically or objectively; instead, they need inductive approaches. The study adopted an interpretivism approach, which is critical for the understanding of interaction with different participants in the community Jackson (2013). The interpretivism approach was chosen based on the differences in geographic, gender, cultural/traditional and age as diversified sources of information about climate-compatible water resources management. This information varied with smallholder farming population groups within the Mazvihwa and Save communities of the Zvishavane and Chiredzi districts.

Interpretivism philosophical approach was chosen compared to positivism philosophy, which generates scientific data (Ryan, 2018), including figures that hide and do not reflect feelings, thoughts, and imaginations, and lived experiences (Park et al., 2020) of smallholder farmers in marginal rainfall areas. Through interpretivism, rich information sources helped the study in answering the research questions aimed at solving climate change and smallholder water management challenges. The assumption about interpretivism as the best fit in this research was that it answered questions related to the study’s case study strategy. Compared to other philosophies, including objectivism and positivism, which rely on scientific measurements to answer the study questions, interpretivism employs an inductive approach. This approach enabled the study to provide in-depth insights, revealing people’s impressions, experiences, and imaginations about climate change's impact on smallholder water resources management.

The interpretivism approach rejects positivism's objectivism approach and views that meaning resides within the world independent of consciousness (Collins, 2010). Adoption of interpretivism in the study enabled that rich information to be induced from communities' local contexts. The smallholder farmers' lived experiences, norms and traditions, structures, and impressions play a crucial role in understanding climate change impacts on smallholder water resources in dry areas. This explained the study's preference for the interpretivism approach that accommodated multiple data collection methods to triangulate and reflect different aspects, issues, and phenomena under study. Interpretivism places more emphasis on conducting research among people than on objects because of the need for the study to interpret climate change impacts on smallholder farmers according to their experiences of the day-to-day effects of climate change on water resources. Saunders et al. (2012) reveals that human beings and their social world could not be studied as separate entities like objectivists do with physical objects, because separating humans from their social setting results in a loss of contextual meaning. These meanings need to be studied and interpreted, hence the need for an interpretivism approach. This philosophy, therefore, helped the study to create new, richer understanding and interpretations of the social world and context, considering different experiences embedded in the diversity and dynamics of the community members.

One key challenge encountered in the interpretivism approach was gaining access to the research participants' social world and understanding the participants' context from their point of view. This challenge did not deter the study since the researcher is a development practitioner and was long exposed to the world where smallholder participants lived. Existing professional connections, linkages, working experience and knowledge about the best entry processes into the community were used to the advantage of the study and allowed gaining access to the participants' context. The researcher, therefore, adopted an empathetic stance that enabled the study to interpret the situation from the smallholder farmers' perspective.

In line with interpretivism, the study employed an inductive approach whereby, according to Kivunja & Kuyini (2017), Jackson (2013) and Antwi & Hamza (2015), enabled data collection and analysis in the research to develop a theory. Through an inductive approach, in-depth interviews enabled the study to understand the context of climate change opportunities and challenges within the smallholder farmers' domain in rainfall-marginal areas.

A case study approach was also used to interpret different scenarios experienced by smallholder farmers. According to Saunders et al. (2012), a case study is a research strategy involving empirical investigations of a particular contemporary phenomenon within its real-life context employing multiple sources of evidence. Therefore, the case study approach helped the research to answer the WHAT, HOW, WHICH and WHY questions that generated smallholder farmers' lived experiences about climate change impacts on their water resources in Zvishavane's Mazvihwa and Chiredzi's Save communities. This approach informed by interpretivism's inductive approach further capitalized on developing multiple cases to triangulate and validate the research findings. Yin (2003) indicated that producing multiple cases is much more preferred to strengthen the study and improve its validity. The research was therefore carried out as a cross-sectional study, providing a snapshot of the time horizon, and took advantage of different events recorded or undocumented and presented as key findings in respect of climate-compatible smallholder water resources management in dry lands.

It is critical to note that research questions rarely fall neatly into only one philosophical domain. This is supported by Saunders et al. (2012) and Turyahikayo (2021). Therefore, the researcher recognized the importance of employing realism philosophy to provide scientific and statistical evidence to strengthen the study. According to Saunders et al. (2012) and Park et al (2020), realism stresses that what our senses reveal as reality is the truth in existence. This realism philosophical positionality was employed in the study, and the advantages of its scientific enquiry that provided helpful information enabled triangulation of qualitative data generated by interpretivism. According to Saunders et al. (2013), realism has two main branches: direct realism, which explains that what we experience through our senses accurately portrays the world. The second branch, critical realism, further argues against direct realism because it stresses that what we experience are sensations and images of things in the world, not real things (Saunders et al., 2013). Therefore, the adoption of direct realism's observations was prioritised. This, therefore, formed a critical juncture whereby the research employed quantitative methodology to provide statistical evidence and scientific enquiries that reinforced the qualitative approach dominating the study (Kivunja & Kuyini, 2017). According to Easterby-Smith et al. (2015), this mixed research approach provides a compensatory design, also known as "Master-Servant" research design that enables one design to cover the weaknesses of the other and function for the fulfilment of the other design. The qualitative design's weaknesses around generalization and the quantitative design's limitations in explaining underlying context were all managed by the compensatory design adopted.

3.3 RESEARCH DESIGN

The research design, according to Pandey & Pandey (2015) and Kothari (2004), provides step by step procedures for research data collection, analysis and presentation. Qualitative research design dominated the study, and as Babbie (2011) indicates, it provides opportunities to describe relationships and events that may be missed by scientific approaches that rely on statistical tests. The qualitative design allowed the presentation of in-depth, open and detailed study issues (Antwi & Hamza, 2015; Durrheim, 2006). The study chose both qualitative and quantitative research designs since the study's foundation included the lived experience of the participants within climate change and their socio-economic context, trend analysis for climate data and field measurements. According to Merriam (2009) in Lapan et al. (2012), understanding participants' lived experiences is crucial in obtaining evidence on how the impact of the phenomena affected them. Turyahikayo (2021) and Antwi & Hamza (2015), also state that tacit and explicit knowledge can be complementary; therefore, qualitative or quantitative data alone is insufficient to explain social events with scientific discoveries like climate change-related discipline under study. The study was cross-sectional in timing. The cross-sectional approach allowed the description of critical incidences of the study phenomena within a given context (Saunders et al., 2012).

3.3.1 DESCRIPTION OF RESEARCH SITES

The study targeted Mazvihwa and Save communal areas of Zvishavane and Chiredzi districts, respectively. Zvishavane is in the southern parts of Midlands province, whilst Chiredzi district is in Masvingo province, covering the South-Eastern Lowveld region (Figure 3.1). The two districts' inherent aridity, accompanied by the changing climate, present signs of increased water stress, land degradation and the related collapse of the rural livelihoods. The Zimbabwe Vulnerability Assessment Committee classified the targeted areas as highly vulnerable (ZIMVAC, 2018). The two targeted arid communities fall under meteorological zone three (III), which, according to the ZIMSTATS (2016), receive mostly below-normal rainfall yearly. These districts are part of the more extensive southern dry lands, which according to ZIMSTATS (2016) and the Meteorological Services Department (2018), extends its geographic coverage to include southern parts of Midlands, extreme southern parts of Manicaland, Matabeleland South and Masvingo province. Having fallen into meteorological zone III, these drylands have a 75% chance of receiving below-normal rainfall on annual seasonal rainfall forecasts. Zvishavane and Chiredzi districts have a very high probability of drought due to erratic yearly rainfall (UNDP, 2009a). This explained these marginal rainfall areas' aridity and vulnerability to climate-related shocks.

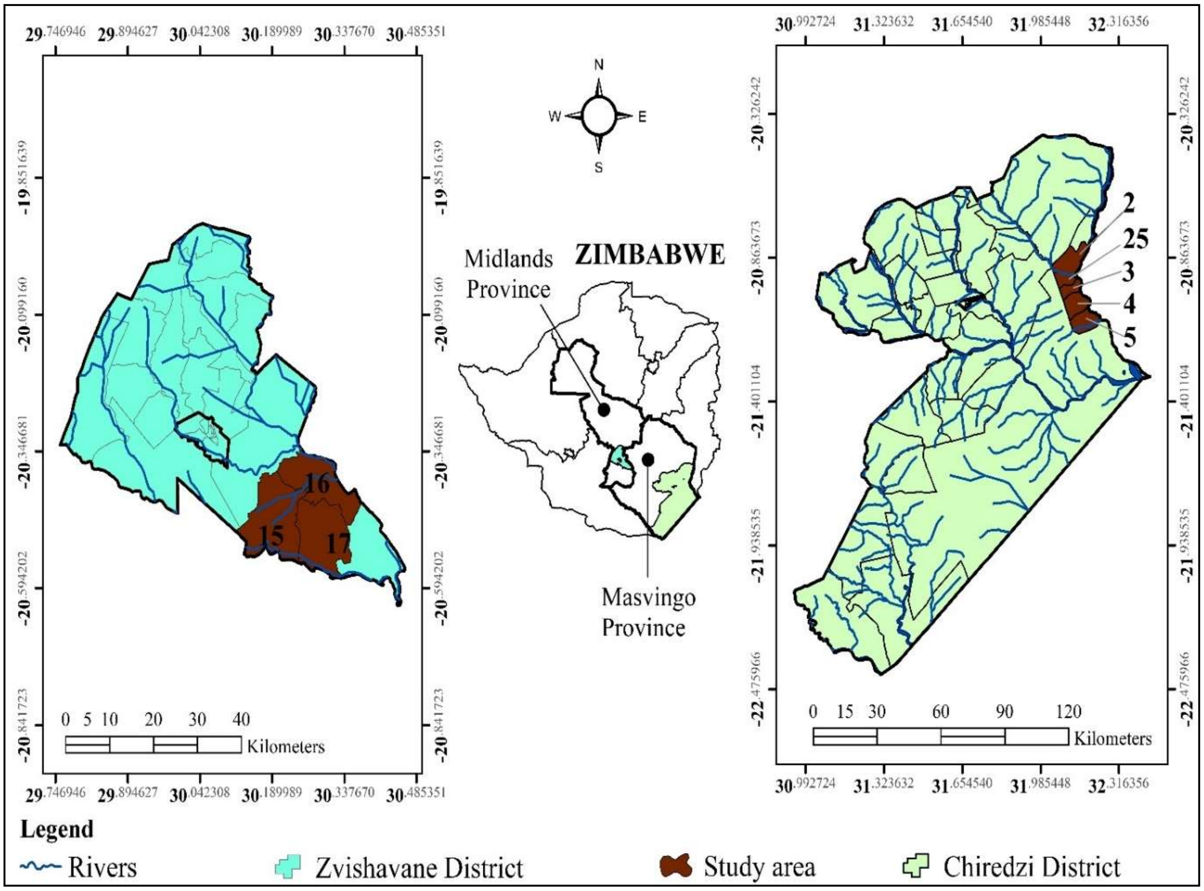

Figure 3.1 Study Sites Location: Mazvihwa (Zvishavane) and Save (Chiredzi)
***Source**: Author, 2019*

3.3.1.1 ZVISHAVANE DISTRICT PROFILE

Zvishavane district population reached 72,513, with 98.7 percent being rural smallholder farmers (ZIMSTAT, 2012a). The district has a total of 19 rural wards, with 14 of these wards falling into the agro-ecological zone (AEZ) IV whilst the remaining 5 falling into AEZ V, which are all arid regions (UNOCHA, 2012). The district is arid and receives erratic rainfall ranging between 450 to 600mm during the October to March rain season. With poverty levels as high as 76.8% in the Mazvihwa area, the vulnerability to climate change impacts remains very high (Government of Zimbabwe & World Food Programme, 2017b). Zvishavane district's population mainly relies on external food aid due to poor harvests (OCHA, 2012). Accordingly, the district is vulnerable to drought (Figure 3.2) hazards, as evidenced by scoring 0.5532 in the mean hazard index under the Zimbabwe Resilience Building Fund's vulnerability rating (UNDP, 2017; Zimbabwe Resilience Building Fund, 2016).

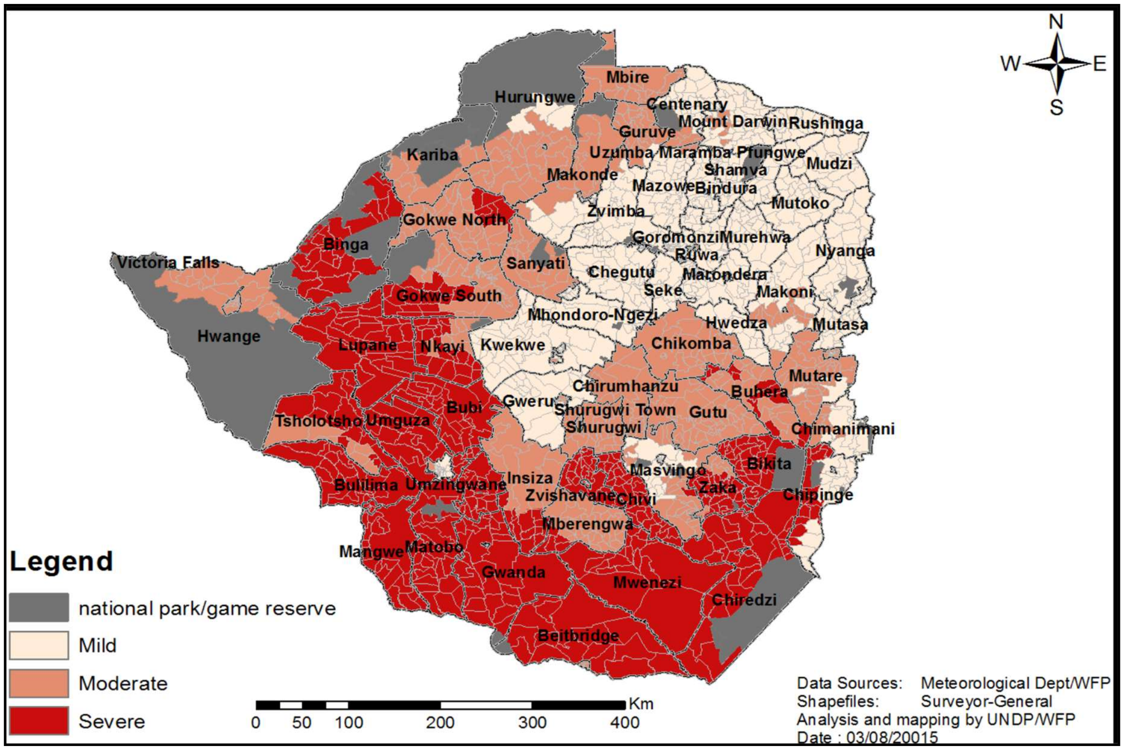

Figure 3.2 Zvishavane and Chiredzi in Drought Prone Areas.
***Source**: Government of Zimbabwe & World Food Programme (2017b)*

According to GOZ and World Food Programme (2017), the Mazvihwa community falls under the Masvingo Manicaland Middleveld Smallholder Livelihood Zone. This zone is dominated by smallholder cereal production, supplemented by some cash crops, which include oil seeds and vegetables. Some livelihood strategies include animal rearing, vegetable sales, and remittances from the diaspora. The sale of wild fruits, illegal gold panning, barter trade, sale of traditional beer, handcrafts and casual labour are some of the community's coping strategies.

3.3.1.2 CHIREDZI DISTRICT PROFILE

Chiredzi rural population reached 275,759 (ZIMSTAT, 2012b), distributed across 32 communal wards covering a geographic area of 17,629 km². Chiredzi district falls under Runde and Save catchments, which are vast arid and drought-prone areas (Figure 3.2). The Zimbabwe Resilience Building Fund (2016) indicated that the Chiredzi district was among the highly vulnerable districts, scoring a 0.6505 drought mean hazard index. A proportion reaching 90 percent lives in communal areas and relies on scarce water resources for livelihood (Government of Zimbabwe & World Food Programme, 2017b). According to GOZ (2015) and UNOCHA (2013), all 32 wards of Chiredzi fall under Agro-Ecological Zone (AEZ) V, where crop cultivation and other livelihood opportunities are difficult to sustain due to water scarcity.

The Save community targeted by this study falls under the Save River Valley and Ndowoyo Communal Livelihoods Zone (Government of Zimbabwe & World Food Programme, 2017a). Despite their high vulnerability to changing climate, the Save River Valley and Ndowoyo Communal Livelihoods Zones depend on crop and livestock production. The dependence on climate sensitive crop and livestock value chain and livelihoods transformed the targeted communities into areas of high humanitarian dependence (World Food Programme, 2021). Other coping strategies for the community targeted include firewood and vegetable sales as well as handicrafts. Cross-border trading is one of the activities that sustains the community. This is mainly due to its proximity to borders and escape routes that include Chicualcuala/Sango for accessing Mozambique, Dite and Beitbridge for accessing South Africa. With the poverty levels averaging 74.6% in some wards, external food aid and social assistance programmes are implemented to protect lives and cushion the community's livelihoods. Chiredzi district experiences some of the country's highest temperatures, an average of +/-39 degrees Celsius, whilst annual precipitation is below 600mm (UNDP, 2009; Government of Zimbabwe & World Food Programme, 2017a). This resulted in high potential evapotranspiration, resulting in unprofitable crop cultivation for communities without reliable supplementary irrigation. Despite the inherent soil fertility, rainfed crops and livestock production by smallholder farmers remained a considerable risk and challenge in the district.

Chiredzi and Zvishavane districts were therefore selected as study sites chiefly because their profiles, geographical location, population dynamics and poverty, as presented by the Government of Zimbabwe & World Food Programme (2017a) revealed high levels of smallholder farmers' vulnerability to climate change-induced water scarcity. This called for an in-depth analysis of underlying factors and strategies that can be adopted for building resilience in support of the "at-risk" communities.

3.3.2 TARGET POPULATION AND SAMPLING PROCEDURE

This section outlines the study's target population and the sampling procedure followed by the study to inform the validity and reliability of data collection tools. Babbie (2011) presented the study population as aggregating all the elements of the sampling frame. The selection of a representative sample enabled the research to allocate resources and time wisely and reduce the number of cases involved in the study without undermining the sample's population representation. The following section details the sampling procedures for enrolling the participants for the questionnaire survey and the stakeholder key informant interviews.

3.3.2.1 SAMPLING PROCEDURES

The smallholder farmers in the targeted Zvishavane and Chiredzi arid districts formed the study population. Representing these smallholder farmers by age, gender, culture, and location was a critical guiding principle in the selection of the sample. The study employed both the probability and non-probability sampling in line with the research questions and information required from various sources. Probability sampling afforded households in the study population equal chance opportunities of enrolling into the study. This eliminated bias in selecting smallholder participants of the research (Taherdoost, 2016). The selection of research participants was based on the subjective judgement, which relied on experience, local context, and data requirements of the research questions. A cluster sampling method was used to select elements from 3 different clusters and four subgroups using random sampling. This allowed equal geographic representativeness of the participants in the study sample. A non-probability or judgemental sampling was employed in the study to determine key informants. This made use of non-randomized methods to draw the desired study sample. Alvin (2016) and Taherdoost (2016) presented non-probability sampling as the best sampling method for descriptive studies. The two scholars credited this method for producing case studies and generating new ideas and solutions to problems.

3.3.2.1.1 SAMPLING, PERCENTAGE, AND RATIONALE

This section focuses more on the determination of a sampling frame, sampling techniques and study sample size. Regarding non-probability sampling techniques, the study employed purposive and quota sampling. Through quota sampling, participants of the study were chosen using predetermined characteristics to ensure the sample depicts the population distribution and characteristics. Men, women, the young, the old, cultural/traditional differences and social structures were considered during the selection of subgroups for quota sampling. Purposive sampling on the other hand is known as judgemental sampling because it deliberately targets specific people, events, and settings of interest to the study (Elder, 2009). These provided helpful information other participants could not divulge in the study context. The involvement of any participant selected through purposive sampling is because the participant warranted inclusion in the research to answer the research questions. The selected participants included key social figures, opinion makers, community influencers or leaders, officials in public offices and community gapers. All these individual participants who showed interest in participating in the study had lived experiences and possessed relevant information pertaining the chronology of the changes in climate events, access to decision-making, planning and governance information required to answer the study questions.

The probability sampling method provided figures and measurements about research questions requiring statistical and mathematical responses in line with the impacts of climate change on smallholder water management. Probability sampling afforded all members of the community an equal chance of being selected whilst reducing any bias compared to non-probability sampling (Singleton & Strants, 2005). Based on the study area dynamics, sample selection of participants from Chiredzi and Zvishavane districts was conducted from ward level to determine participating wards, to village level to determine participating villages and down to the household level to determine respondents of the household questionnaire surveys.

Determining a sample size was an important stage for ensuring statistical and analytical generalization of the study results (Onwuegbuzie & Collins, 2007). In principle, whilst the sample must represent the entire study population, Elder (2009) stresses that a sample must allow the study to "extrapolate inferences, within known and acceptable margins of error, from the sample to the wider population." To enrol smallholder farmer participants, the study employed a two-stage sampling procedure to determine the final participants, as detailed in the following section.

i. Wards and Villages Selection: Purposive Sampling

Purposive sampling technique was used to identify the communal wards and villages whose smallholder farmers have the potential to yield research information in line with climate compatible smallholder water management strategies. According to Semasinghe (2019) and Smith & Albaum (2010), purposive sampling had an advantage in applying subject expert knowledge and context-specific judgement over the study to inform the selection of participants. Purposive sampling capitalized on a logical manner in selecting the participants rather than the random approach mainly deployed in quantitative studies (Semasinghe, 2019). This ensured that all non-response errors were eliminated in the study, increasing the research's validity and reliability.

Out of a total of 37 wards that are in agro-ecological region V (32 in Chiredzi and 5 in Zvishavane), the study purposively selected eight wards (5 in Chiredzi and 3 in Zvishavane) where farmer groups and individuals have experienced more climate change impacts on their water resources. Twenty-two (22) villages from the two districts were selected purposively as sources of information on climate-compatible smallholder water resources management.

ii. Households Selection for Semi-Structured Questionnaire Survey

A formula by Kothari (2004) was used to calculate household questionnaire survey participants and determine the infinite sample size:

a) <u>Determining the sample size for the infinite population</u>

Sampling formula or equations:

$$S = z^2 * p * (1-p) / M^2$$

Whereby S = sample size

Z = confidence level (95% acceptable in social science = 1.96)

P = proportion of population with desired characteristics (50% = 0.5)

M = acceptable margin of error (5% = 0.05)

$$S = 1.96^2 * 0.5 * (1 - 0.5) / 0.05^2$$

$$= 3.8416 * 0.5 * (0.5) / 0.0025$$

$$= 3.8416 * 0.5 * 200$$

$$= 384.16$$

Therefore, S (sample size) = 384

b) <u>Determination of the sample size for the required/adjusted population</u>

Sampling formula or equations:

After compiling the 14,119 household list from eight wards covered by the study, a formula was used to select a representative sample size as follows:

The study took the second stage and used the infinite sample size of 384 to calculate the desired sample size from the sampling frame of 14,119 (with Chiredzi and Zvishavane having the desired population of 8,197 and 6002, respectively) as follows:

$$\text{Adjusted S} = (S) / 1 + \left((S - 1) / \text{population}\right)$$

Whereby adjusted S = required sample size from the sampling frame

(S) = 384

$$\text{Adjusted S} = 384 / 1 + \left((384 - 1) / 14{,}119\right)$$

$$= 384 / 1 + \left(0.02713\right)$$

$$= 384 / 1.02713$$

$$= 373.8$$

Therefore, the adjusted (sample size for the study) is 374

After determination of the sample size, a simple random sampling method was used that afforded each participant equal chances for enrolling into the study. Random sampling method is considered one of the most accurate methods for choosing a sample from the population. It is best for studies that generalize the results to the broader population (Elder, 2009). Elder (2009) stressed that for simple random sampling to be practical, the updated sampling frame should be readily available. In this case, the study used the updated village registers provided by the local leadership. From the village registers, the study took the following steps to come up with a randomly selected sample:

i. Generated an exhaustive list of the sampling frame from village registers,
ii. Develop a computer-generated random table to determine the participants, and
iii. Selected participants were approached for the administration of the questionnaires.

For anonymity, all household participants were coded ZHR and CHR, where the first letter (Z or C) is a check letter representing the study area, Zvishavane (Z) and Chiredzi (C). HR after the check letter represented Household Respondent in the study. in other words, ZHR = Zvishavane Household Respondent, and CHR = Chiredzi Household Respondent. Each respondent was allocated a unique number from 1 to 165 for Zvishavane and 166 to 374 for Chiredzi district.

3.3.2.2 SAMPLING FOR KEY INFORMANT INTERVIEWS AND FOCUS GROUP DISCUSSIONS

Purposive sampling was employed for selection of key informants and participants of the Focus Group Discussions (FGD) were selected using the same. (Singleton & Strants, 2005)(Singleton & Strants, 2005)According to Lapan et al. (2012), purposive sampling is a non-random probability sampling technique. It was employed to select respondents with rich knowledge and experience from smallholder water and climate change interaction. The study employed expert judgement to determine representative participants and smallholder farmers, supported by Singleton & Strants (2005). The participants selected for focus group discussions (FGD) and key informant interviews (KII) included local authority officials, traditional leaders, community-based organizations, NGOs working in the area, and officials from government departments (Table 3.1). The selection of these participants was guided by Innes & Connick (2001), who emphasized the need for enrolling those capable of discussing in detail the research questions and sharing informed views better than other members of their community.

Table 3.1 Stakeholders Selected and Importance in Participating in the Study

Research Participant	Number	How Participant was Contacted	Reason for Selection
Local Authority (RDC) officials	2	Phone calls and arranged face-to-face meetings for interviews at a place and date convenient to participants. In most cases, meetings were held in respondents' offices.	The role of the RDCs was mainly service delivery and regulation for all the operations in the district. They control development space for all actors and developers in the district. They were sources of information, reports and plans for their areas of jurisdiction.
Local Community Leadership	14	The Rural District Council officials mobilized Ward Councillors and traditional leaders, and convenient meeting schedules were agreed upon. The KII were held in local communities.	6 Ward Councillors and 8 Traditional Leaders were vital since they coordinated traditional and developmental activities. They are the custodians of the community. They provided critical historical information and permission for the farmers to participate in the study.
Community -Based organization or local NGO	2	Phone calls were used to arranged face-to-face meetings for interviews and research teams travelled to agreed	Have ongoing community development projects in Chiredzi and Zvishavane districts. They work with the target group of smallholder farmers.

representatives		meeting places for interviews.	
Local extension services providers	8	Heads of government line departments and local authorities helped to mobilize their respective extension services officers for KII meetings	They offered specialized training, linkages, programme monitoring, evaluations and information to smallholder farmers targeted by the project. They possessed critical institutional memory and information about climate change and water resources in targeted communities.
Government heads of crucial departments (EMA, ZINWA, DDF, AGRITEX)	12	The use of phone calls for arranging face-to-face meetings for interviews at convenient places and dates with representatives was done. The research team travelled to the meeting places.	These had institutional knowledge, policy and program directions about the districts that served. Government officials were selected since they provided regulatory, technical and policy support and planning functions for the smallholder farmers.
Community-based water management structures (including individuals and committees selected at the community level)	11	The research team requested support from district-level and ward-level leadership to help with the mobilization of these structures to attend a meeting voluntarily. Meetings between the research team and these structures were done through local leadership facilitation and protocols.	These are critical players in community-based water resources management. They included six water point committees, four irrigation management committees, four village pump minders, two dip tank committees, two dam management committees, and 3 DRR committees in Chiredzi & Zvishavane.

Source*: Author, 2021*

To maintain anonymity, the following codes were used for referencing data collected during key informant interviews and focus group discussions. Local Authorities were coded ZLAR and CLAR. The LAR after the check letter represented Local Authority Respondent. The code LCL was used for Local Community Leaders, CBO was used for Community based organizations/local NGO, local extension service providers used LEP, government department heads used GVT and CWM was used for community-based water management structures. In all codes, the first letter (Z or C) is a check letter representing the study area, Zvishavane (Z) and Chiredzi (C).

3.3.3 DATA INSTRUMENTATION

This section provides details about different tools used by the study for the collection of data. Since the study used mixed methods, instruments for capturing qualitative and quantitative data were used. At least three types of data sources were considered adequate in measuring the reliability of the research results, in line with Lapan et al. (2012). A household questionnaire was used to gather responses from 374 participating smallholder farmers. Key informant interviews were conducted, and respondents included officials from local authorities (Runde Rural District Council and Chiredzi Rural District Council), government line ministries' district level departments, local extension services providers and CBOs or local NGOs provided insights about the study. Focus Group Discussions (FGDs) were conducted drawing community-based water management structures, including water point committees, dip tank committees, irrigation committees, and dam committees, to gain insights, draw lessons and move forward recommendations from their lived experiences in managing water resources. A mixed methods approach was used to tap information from different participants. This method was vital in strengthening the research findings' validity and levels of reliability. In this research, data collection tools varied widely and remained guided by the research questions.

3.3.3.1 SEMI-STRUCTURED HOUSEHOLD QUESTIONNAIRE SURVEY

When considering the changing climate scenario in dry lands and smallholder water management, their bearing and impacts on rural livelihoods, economies, and natural resources base determine power dynamics within a locality's social and economic setup. Smallholder farmers' household questionnaires (Annexure 2) were administered to 374 randomly selected participants in Chiredzi and Zvishavane districts. These questionnaires gave the participants room to explain the context and underlying problems, which helped to capture case studies relevant to the research questions. The questionnaire was the preferred tool deployed since it works much better in unfamiliar settings. This helped the study to manage data collection in sensitive and complex environments, supported by Kielmann et al. (2012). Semi-structured questionnaires could capture a compendium of responses from participating smallholder farmers. Data collected was in-depth, cross-cutting and centred around smallholder farmers' demographics, livelihoods, land tenure, water resources, energy efficiency, technology, information sources, household income, agricultural productivity, and climate change-related information that the farmers experienced over the years that they lived in the community.

3.3.3.2 FIELD OBSERVATION

The participant-observer (Annexure 9) was employed to capture important information on human activities, interactions, practices, and behaviour concerning climate change and water resources management as they unfold in real-life situations. According to Kielmann et al. (2012), this provides a vital conduit necessary for linking and interpreting interview gathered information to the reality that exists and is observed in the local context. After being systematically planned, conducted, recorded, and interpreted, field observation enabled the study to collect data as well as learning things that participants were not willing to discuss candidly in an interview or focus group discussions. Observations notes captured included the place, date, time, purpose and context or actions that were unfolding without value judgement from the note taker. Analytical notes were added to the observed situation by interpreting the observed context and drawing the appropriate conclusion.

Finally, emic reflexive notes were added to pinpoint whether there was the researcher's influence in the observation, which was vital in the management of the observation's data quality. The field observation was critical in providing additional evidence to information known and those gathered through other data collection tools (Kielmann et al., 2012). Field observations provide deep information about the problem under study and about associated events captured through observation.

3.3.3.3 KEY INFORMANT INTERVIEWS

Interviews with key informants (Annexures 3 to 6) participants were purposively selected as detailed in the sampling procedure section. This was done by targeting persons with relevant professional backgrounds, experience, and unique skills concerning the study subject. Key informant interviews targeted office bearers and individuals who had access to other information of interest based on their official position and work experience. Community leadership, extension services providers, representatives of CBOs or NGOs and government department representatives working in the target districts such as AGRITEX, research institutes, local authorities, traditional leaders, master farmers and other opinion leaders were targeted as information sources pertaining institutional roles and capacity in enhancing climate compatible smallholder water management in dry lands.

In selecting key informants, the study chose the individuals based on specialized knowledge, the position of influence in the community, duties or mandates of their office or position and having first-hand information about the study topic. This was supported by USAID (1996), which emphasized the need for engaging key informants with access to context and official information. Key informant interviews were conducted after establishing a rapport and maintaining ethical conduct and professionalism between the researcher and the informant. The study used probing techniques to dig deeper for clarification and areas of interest that required follow-up questions. The process continued and maintained neutrality from asking questions, probing, note taking and even during data analysis after the interviews. Key Informant Interview (KII) were used because of the advantage of knowledgeable informants that provided first-hand information and sometimes referred to written records that were later given to the researcher as reference documents. To safeguard against bias, neutrality was maintained and guided the process from diverging to other exciting topics that were not beneficial to the study.

3.3.3.4 FOCUS GROUP DISCUSSIONS (FGDs)

Representatives of community based water management structures participated in FGDs (Annexures 7 to 8). Mishra (2016) defines FGDs as "a form of group interviewing in which a small group, usually ten to twelve, is led by a moderator (interviewer) in a loosely structured discussion of various topics of interest." According to Kielmann et al. (2012), focus group discussions gather information about the research participants' shared understanding of the problem and its context. Hennink (2014) and Rea & Parker (2014) indicated that the selection for a discussion must be coherent and have a shared interest in the subject topic under study. Most scholars deploy focus group discussions as a quick way of gathering or generating rich context-specific research information. Fern (1982) in Hennink (2014) supported this same notion. The scholar further indicates that one focus group discussion conducted adequately can generate an average of 70 percent, the same information that can be gathered through in-depth interviews and using the same number of research participants. The study took advantage of the tool, capitalized on the group's dynamics, and used group interactions to collect more research data that interviews, and questionnaires might have missed.

Focus Group Discussion was further commended for this mixed method study to augment the qualitative data collection process. It, therefore, helped the study to generate new concepts and proven ideas from lived experiences, gather essential background information on the study, weigh the potential and impact of the events or problem, adding to the interpretation of secondary data gathered by other sources as explained by Stewart et al. (2009). During the study, 21 FGDs conducted and helped to identify the trend of the responses if they represent reality on the ground. The researcher based his judgemental on group members' behaviour, body language, facial expression, perceptions, and emphasis on specific points to pinpoint the group's consensus on opportunities and constraints related to climate change, and local institutions' roles and capacity.

The study followed the critical stages that formed the standardized approach and guidelines, which were set and confirmed by scholars and organizations, including USAID (2011), Baral et al. (2016) and Dilshad & Latif (2013). The researcher took the facilitatory role, identified groups and participants, and agreed on the time and the conducive location for conducting the discussion. The facilitation team was guided by a focus group guide already developed and approved by the ethical committee. The facilitators ensured that the group discussion was kept on track by implementing checks and balances. Free participation by all group members was encouraged, while the research team continued with a moderation role, and kept checking any member who had the potential to dominate the discussion. During the discussion, the research assistants did record the proceedings and note-taking. After completing the day, the researcher analysed the data collected. As supported by Dilshad & Latif (2013), focus group discussions were critical in exploring and understanding underlying issues within the smallholder farmers' context. By targeting smallholder women, men, and their water management committees, the study understood key underlying factors, perceptions and lived experience in climate-compatible water resources management in rural communities.

3.3.3.5 DIRECT MEASUREMENTS

According to OECD (2015), direct measurements for data collection in research are conducted by placing a desired and appropriate measuring device or instrument at the appropriate distance of the feature of a component, enabling the researcher "take a discrete measurement" over a defined length of time and taking the readings. In this study, direct measurements were carried out in Chiredzi and Zvishavane districts communities as identified and agreed with research participants during field observations. Direct measurements were carried out on selected sites to determine groundwater availability using a PQWT exploration machine developed by Hunani Puqi Geological Exploration Equipment Institute (n.d.). The PQWT is an advanced resistivity machine that uses electromagnetic energy to collect sub-surface data and generate outputs about subsurface hydrogeological formation in three primary forms.

The curve map or scatter graph is the first output generated during data collection when electromagnetic energy sends back signals to the receiver. After completing the line investigation with the scatter graph generated, the operator commanded the generation of a sub-surface resistivity profile of the investigated area. The operator commanded converting the general resistivity sub-surface profile map into a high-resolution processed map that separated the zones of different resistivity using contours and colour codes. The PQWT exploration machine generates and displays contour lines depicting underground reservoirs, geological fractures, folds, and fault lines. These were displayed on a contour chart with colours ranging from red for highly resistant parent rock material profile with no chances of water to yellow, light blue and dark green; the latter depicting less resistive materials, highly weathered or regolith with increasing order of groundwater occurrence.

The study employed the measurements by PQWT exploratory equipment due to its advantages. Exploratory teams best know the equipment for its high speed in taking measurements. It is ten times faster than traditional resistivity equipment like ABEM Terrameter 300. Accurate results and good performance were an advantage attained by the machine's capability to make use of 0.001 Mv resolution, and the precision of the equipment is +/- 2 percent (confidence level). Unlike other electronic measurement devices, the PQWT has an anti-interference property through the inbuilt advanced anti-jamming technologies that make it most suitable for remote areas with obstructions. The machine came with a user-friendly interface and was equipped with an interactive manual, making its use and operations a Do It Yourself (DIY). It therefore required fewer skills, just familiarization. The most important advantage gained by the research from the PQWT machine is the system's automated measurement, recording, data storage and output generation nature, making it less demanding to generate analysis and interpretation. The generated sub-surface profiles were given specific codes based on the line numbers from any number ranging between 0001 and 1000. The site profile name was entered in the notebook for easy reference when the final output is exported and saved on a computer in pictorial "*.png"* format or Microsoft Office Excel.

The choice of location was based on the responses by participants to data collection tools including FGDs, KII and questionnaires on the availability, use, sustainability, and vulnerability of groundwater in different areas. Professional judgement and expert information were vital in determining the areas to be administered PQWT machine's direct measurements.

Precision, in this case, refers to the agreement among replicates of measurements of the same property under a prescribed condition defined by OECD (2015). The researcher ensured that the precision issues around the measurement device would not affect the quality of work. The operator precision was solved by using and adhering to the device's standard operational procedures (SOPs) in the user manual. Two operators used the instrument at the same position. Both operators maintained identical calibrations to take measurements to confirm the other operator's findings. Instrument precision was managed by maintaining the batteries' power levels and adhering to the calibration requirements of the manual. All the measurements were operated in a single frequency measurement state, under energy gang zero, calibrated to measure up to a maximum of 150 metres depth and used the same measurement demarcated line with a minimum of 10 points within each line. Therefore, the operator and equipment precision were guarded against since these are critical considerations for data quality when direct measurements are deployed in studies, in concurrence with OECD (2015).

3.3.3.6 CONSENSUS BUILDING MEETINGS

Consensus-building meetings is an interactive "face-to-face discussions among participants, joint learning and the development of a shared understanding of the context" as Innes & Connick (2001) explains. It is valuable in triangulation and validation of the study findings by representatives of study participants. The key steps involved resulted in the success of the consensus-building meetings, including the planning stage. At the planning stage, the researcher requested assistance from community leaders, including Ward Councillors and the AGRITEX Cluster Supervisors, to organize two hour meetings in a central venue. The process drew participants from representatives of smallholder women, men, local leadership, water point committees and asset management committees for the smallholder irrigations. The meeting presented the study's central themes, findings and critical events for further discussion and validation. The responses were further captured and classified into three sections: critical areas of agreements, new information and diverging views for further interrogation and synthesis into the reports. One key challenge of consensus building includes the over dominance by key individuals. The study ensured the balanced representation and facilitation was conducted to ensure equal and levelled participation by all members selected. A multi-level validation facilitation was adopted to ensure key government and district level KII respondents, community-based extension services providers and smallholder farmer groups at community ward levels were engaged separately. Gender and other intersectionality were considered in selecting consensus building meeting participants.

3.3.3.7 SECONDARY DATA / DOCUMENTARY ANALYSIS

This study benefited from the extraction of archived secondary information from repositories, reports or other written, recorded sources of materials that were not gathered and prepared for the research under study (Lincoln & Guba, 1985). According to Smith & Albaum (2010), secondary information is "information that persons or agencies have collected for purposes other than the solution of the research problem at hand." In addition, Braun & Clarke (2006), Corti et al. (1995) and Dale et al. (1988) further notes that secondary data could be both in qualitative and quantitative forms that have been in existence after being collected for other purposes by different persons or organizations.

Secondary information was collected from the Zimbabwe Vulnerability Assessment Committee (ZIMVAC) reports, AGRITEX, Chiredzi Rural District Council, Runde Rural District Council, ZINWA repository, Meteorological Services Department, UNDP portal, Zimbabwe Statistical Agency (ZIMSTAT) portal, district profiles and reports from development organizations. These data sources were complementary and enabled triangulation to validate the reliability of information gathered in response to the research question. Secondary data was also crucial as a climate change tracker in policy development, developmental programs, council resolutions and strategic priorities. Secondary data was acquired cheaply, required less time to gather, and the data was of high quality that went through peer review processes and quality control aspects. In this study, it was advantageous for the study to get climate information, including rainfall and temperature, that was gathered from meteorological services and helped provide longitudinal information required for trend analysis. According to Braun & Clarke (2006), secondary data has one disadvantage: a lack of familiarity, which may affect the researcher's control over it, especially in cases with missing data sets. The study, however, employed some safeguards against these shortcomings on secondary data by ensuring cross-referencing data with officially approved and peer-reviewed data.

3.3.4 DATA ANALYSIS

This research employed data analysis techniques covering qualitative aspect and quantitative requirements that benefitted the research through data visualization, exploratory analysis, and trend analysis, which were critical in guiding the presentation of research findings. The following section presents data analysis covering quantitative as well as qualitative analysis.

3.3.4.1 QUANTITATIVE DATA ANALYSIS

Quantitative data analysis was conducted using Statistical Package for Social Sciences (SPSS) version 16.0 and Mann Kendal Trend Test (M-K Test) XLSTAT 2021.3.1 (Addinsoft, 2022). The deployment of these packages was helpful in providing data analysis using parametric and non-parametric tests per the data collection requirement. The details of quantitative data analysis packages are in the following section.

i. Statistical Package for Social Sciences (SPSS)

The Statistical Package for Social Sciences (SPSS) is a windows based software used to capture and generate statistical data analysis (Arkkelin, 2014). The study employed the SPSS package in data analysis because of its versatility, accommodating different types of data analysis, data transformation and generation of statistical outputs (Arkkelin, 2014).

The researcher used the SPSS software for statistical measurements of data collected from the Household Questionnaire Survey. It made the data analysis easy since SPSS was able to handle the analysis of massive data, generate statistical presentations and conduct analysis for different variables to provide descriptive and inferential statistics that best fit this mixed methods research (IBM Corporation, 2012; Landau & Everitt, 2004). The SPSS package was used to generate the descriptive statistics of the study population and research findings. According to Pandey & Pandey (2015), descriptive statistics are a useful measure of central tendency (mean, median, mode), variability (deviation of data collected from the mean) and relationship among data collected (Box et al., 2016; Gadedjisso-Tossou et al., 2021; Glen, 2016; Meals et al., 2011; Charlton & Caimo, 2012). Inferential statistics were vital in the data analysis of this study as they provided the significance of differences between the data means, which determine whether a true statistical difference between data means existed. The study used inferential and descriptive statistics, and the graphs were generated from SPSS, thus enabling the researcher to explore the research data.

ii. Mann Kendall Trend Test (M-K Test)

Mann-Kendal test is a non-parametric test (Gadedjisso-Tossou et al., 2021; Glen, 2016), grounded on the null hypothesis that there is no trend in the data under observation. The study used the M-K test to analyse "a sequence of observations taken sequentially in time" (Box et al., 2016). According to Meals et al. (2011) and Glen (2016), the M-K test evaluates whether the Y values increase or decrease over time. Furthermore, Meals et al. (2011) highlighted that the Mann-Kendall trend is based on one fundamental assumption that "no values can always be declared less than, greater than, or equal to another value", which awarded the climate data under analysis some levels of independence. As alluded to by Charlton & Caimo, (2012), MK-test supported the study with descriptive climate events that unfolded over time, providing inference about patterns in data in a time series. This enabled the study to identify the cyclicity of events in cases associated with recurrence after a certain period and stationarity where no changes are identified in the trend.

The study benefitted from the M-K test when analysing historical climate information collected from 1900. The M-K tests do not require pre-requisite for data to be normally distributed. Cases of missing data can be allowed as data do not require conformity to any specific distribution (Gadedjisso-Tossou et al., 2021; Meals et al., 2011). According Meals et al. (2011), the test's capability was based on its capacity to handle analysis for data which forms different trends, including monotonic, which occurs gradually and consistently over time. Step trend, which denotes to trend from data that has an abrupt shift at a certain period point, was also easy to analyse with M–K tests. This was key in the study concerned with capturing critical events related to climate change and smallholder water resources management. Mann-Kendall tests played a crucial role in data analysis by providing room and capacity for predicting future trends through analysis of the past and current trends, as supported by Box et al. (2016). Based on the prediction capacity, as alluded to by Ihaka (2005) and Charlton & Caimo (2012), the study was able to suggest control measures and advisories, propose frameworks and propose climate and water-related policy direction.

3.3.4.2 QUALITATIVE DATA ANALYSIS

Qualitative data analysis was the major component of data analysis used for this study since the research was more inclined to an inductive approach that gathered data using unstructured situations. In line with Nigatu (2009), qualitative data analysis is based on interpretative philosophy, examining the meaning and symbolic contents of the qualitative data. The data that required analysis was represented in the visual, narrative, and verbal forms that require various strategies, including visualization, exploratory analysis, trend analysis and estimation strategies, to generate meaning.

Critical methods used in this study's qualitative data analysis include event or micro analysis, content analysis, phenomenology or heuristic analysis, narrative analysis, and profile map analysis (making use of the colour chart analysis), as detailed in the following sections.

i. Event Analysis / Microanalysis

This technique focused on finding the beginning and ending elements of events presented by the research participants, as supported by Frederick (1992). This enabled the study to identify exciting events and characteristics that mark the events' boundaries. Drought periods, floods, heatwaves, economic shocks, political developments, and crop and livestock disease outbreaks formed a collection of events remembered by the research participants that impacted water resources management in dry lands. This technique was the best fit for the case study research approach employed in the study.

ii. Content Analysis

Patton (2002) defines content analysis as a process for data reduction and generating sense from volumes of qualitatively collected data to identify critical consistencies and meaning behind the data. Leedy and Ormrod (2001), in Haradhan (2018), define content analysis as "a detailed and systematic examination of the contents of a particular body of materials for the purpose of identifying patterns, themes and biases." Content analysis was employed in this study to identify themes from speech, impressions, expressions, emotions and spoken words by the research participants. Nigatu (2009), indicates that content analysis plays a critical role in providing descriptive and interpretive techniques for data analysis by explaining the different elements and meanings of data gathered in the study. This technique allowed information to be classified, summarised and tabulated to provide a clear description and interpretation of the meaning of the data. The content analysis helped the study identify the discourse and the relationship between the content and the context. Because of its capability to work with qualitative and quantitative data, context analysis was helpful in handling data collected using mixed methods.

In terms of procedure, the study followed step by step processes in data analysis utilizing content analysis:

a) Data preparation was a step taken to bring to the table all the data from various and diversified sources in preparation for analysis. The data gathered included the narrations, questionnaires, photographs, secondary information, focus group discussion, and key informant interview notes collected by the research.
b) The next stage of defining key units and theses of data analysis was followed. Guided by the research questions, the study identified keywords, phrases, and categories that suit the data without falling into the generalization trap. This was further reviewed to ensure that the categories were not leaving out some of the information without a perfect fit section. The four main categories followed by the study were climate change impacts, institutions, strategies, and recommended actions.
c) Developing a coding scheme, categories and subcategories were the following steps to ensure further categorization of data into respective sections to avoid clustering information and generalization. Therefore, the categories and subcategories were tested for consistency to ensure clear boundaries for data that indicated overlapping chances. Re-definition of the categories and subcategories was therefore carried out in cases where overlaps existed because of generalization.
d) Data were coded after pretesting and later entered into respective categories using Microsoft Office Excel-generated database entries. Within the categorized entries, data was assessed for both validity and reliability. This ensured that data which fitted perfectly in the respective sections remained categorized for further analysis. Data entries that did not fit into categories were re-assigned to other subcategories or removed.
e) Drawing conclusions, identifying relationships, commentaries and inferences were conducted from the categorized thematic data.
f) Finally, the results were presented from the conclusion, inferences, and relationships identified to prepare the report for the readers to understand the interpretations conducted.

The qualitative data analysis about lived smallholder farmers' experiences generated rich findings for the study in line with the research questions around water resources management in dry lands. Through context analysis, huge volumes of data were organized and used to generate thematic results that provided both relational and commentary meaning about the findings.

iii. Heuristic Analysis / Phenomenology

Phenomenology, also known as heuristic analysis, is concerned with understanding how the research participants view and experience the study context. According to Haradhan (2018), it is an "approach to explore people's everyday life experience" and is most commonly applied in data analysis "when the study is about an individual experience on a phenomenon every day." This was therefore applied in line with the views of Creswell (2013) to gather a deep understanding of the underlying meaning emanating from issues unearthed by the study. Phenomenology allowed the study to analyse data and present information about how different individuals experience the world of climate change and smallholder water resources management in Mazvihwa and Save communities. This approach was vital in helping the study generate case studies that captured the memories, experiences, imaginations, and perceptions of research participants living in marginal rainfall areas.

iv. Narrative Analysis

According to Denzin & Lincolin (2013), the narrative analysis applied in this study context refers to "making meaning through shaping or ordering experience" shared by research participants. Furthermore, Denzin & Lincolin (2013) indicate that narrative analysis can be in the form of oral history, which the scholars described as "collecting and interpreting human memories to foster knowledge and human dignity." This study considered that people from different socio-economic and geographic contexts have different experiences about climate change impacts on smallholder water resources management. Their shared stories required some reformulation into a format readable and understood by the larger audience, as supported by Babbie (2011).

v. Profile Map Analysis

The profile map analysis used the sub-surface colour chart and contour analysis techniques as informed by Hunan Puqi Geological Exploration Equipment Institute (n.d.). The study analysed the processed sub-surface profile map for different borehole sites established, that are both perennial and intermittent in terms of water supply. This was conducted by checking the vertical axis, which indicated the profile's depth concerning the borehole's depth. The depth aspect of the profile map gave indications of the level of the water table and the water-bearing rock.

Secondly, contour analysis was conducted by checking how the horizontal axis was arranged in relation to each other. Besides checking the adequacy of the number of points measured in metres, the changes in the arrangement of contours from one point to the other were paramount to the study. Taking note of the contour values, the study analysed groundwater presence or absence based on local hydrogeological formation and resistivity presented by the colour chart, in line with the user manual by (Hunan Puqi Geological Exploration Equipment Institute, n.d.).

3.3.5 METHODOLOGY REFLECTION

The study was guided by the provisions of the ethical clearance issued by the University of Witwatersrand under Protocol Number H20/08/18 (Annexure 1). Ethical clearance enabled the researcher to commence data collection. During data collection, the researcher ensured that every tool used satisfied the thresholds to ensure theoretical saturation. According to Kielmann et al. (2012), theoretical saturation is a critical determinant that assesses if the samples selected in the study are large enough to provide adequate answers to all the set study questions. Therefore, the number of focus group discussions and key informant interviews was enough to ensure triangulation of information collected by various tools or generated from different participants. Key informant interviews and focus group discussions were conducted with targeted participants until no new or relevant information emerged. The research took note of relationships and patterns for all the study categories established from the data collection process, as supported by Kielmann et al. (2012).

The study was conducted during the COVID-19 context. Permission and clearance for conducting the research in the communities were sought and finally granted in all the two districts under strict COVID-19 compliance (Annexures 22 to 29). Therefore, the research process required additional financial resources to procure personal protective materials, including face masks, sanitizers and infrared thermometers required for the data collection process to comply with the COVID-19 regulations and context in Zimbabwe. An additional research assistant managed COVID-19 regulations by offering temperature screening, managing social and physical distances, and distributing personal protective equipment (PPE). During the entire research process, no cases of COVID-19 infections were recorded on research participants, the researcher, and his assistants. Access to all the participants was a challenge due to other competing activities. Additionally, the COVID-19 context in the year 2021 required the decongestion of both public and private offices and working spaces. Lockdown regulations were enforced depending on the level determined by the authorities. It was, therefore, a challenge to set up successful appointments and meet all the key informants in one visit since most of them were working from home and away from workstations. The researcher made several visits from Gweru to the study area's districts of Zvishavane and Chiredzi, which required, on average, 256 kilometres and 682 kilometres of return trips, respectively. Several long-distance trips were embarked on, to complete the data collection processes.

The language barrier was challenging for collecting data from the Chiredzi district's questionnaire participants. The Save community had a mixture of the Ndau, Shona and Shangani-speaking people and a significant proportion of the smallholder farmers required some translation of the questionnaire contents. The researcher had a basic understanding and speaking of the Shangani language. Three experienced research assistants who were government extension services officers working in the same communities were engaged to interpret and translate questions at the community level. The research assistants were recruited in Chiredzi from the research team with the two assistants that worked with the researcher throughout the data collection and analysis stage. To ensure good data quality, the research assistants were pre-trained and later paid their daily subsistence allowances for the services. Due to the high data volumes collected through all the processes, the researcher engaged the research assistants for additional costs to manage the checklists and collate information. This was associated again with transport, accommodation, and upkeep costs paid by the researcher to the research assistants. Considering the highlighted constraints, the research's data collection process required additional financial resources to ensure smooth operations.

Because of the seasonal livelihoods calendar, farmers in the targeted communities have a set of activities that they do depending on the time of the year. In Chiredzi, field visits for meeting with smallholder farmers were initially conducted between October and November 2020, whilst the Zvishavane smallholder farmers' field visits were conducted between December 2020 and February 2021. In Chiredzi, the farmers were already anticipating the rains to prepare for their new agricultural season. It was the hottest period of the year in Chiredzi. Competing events in the Zvishavane district, including the onset of rainfall and farming activities between October 2020 and May 2021, required the researcher to visit the areas several times to complete all data collection processes.

CHAPTER FOUR

PRESENTATION OF EMPIRICAL EVIDENCE

4.1 INTRODUCTION

This chapter presents the findings of the study. The study's empirical evidence was presented in statistical, case studies, maps, and explanatory format in line with the mixed methods used. Climate change impacts on smallholder water resources were associated with droughts, changing rainfall patterns and an increase in the average temperatures that affected crop production and livestock health, resulting in water scarcity affecting the communities in the study areas. Key opportunities, including water harvesting, increased funding mechanisms for climate change-related policies and projects, and technological transfer, are some of the gains that smallholder farmers have realized since the escalation of climate change discourse at the community, program and policy levels. Findings on the strategies proposed for adoption by smallholder farmers were also presented. This chapter on the presentation of empirical evidence is arranged into five (5) main sections, with this introductory section 4.1 being the first. Section 4.2 was presented as the second covering climate change-related opportunities and constraints, while the third section 4.3 presented local institutions for climate-compatible water management. The fourth and fifth sections, 4.4 and 4.5, covered the findings on the strategies that can be adopted for climate-compatible smallholder water resources management and the conclusion, respectively.

4.2 CLIMATE CHANGE OPPORTUNITIES AND CONSTRAINTS FOR SMALLHOLDER WATER MANAGEMENT IN DRYLANDS

The study sought to answer a research question identifying climate change related opportunities and constraints for smallholder water management in dry lands. This section presents study findings pertaining to the first objective on climate change-related opportunities and constraints for smallholder water management in the study area.

4.2.1 CLIMATE CHANGE, WATER RESOURCES AND SMALLHOLDER FARMERS IN CHIREDZI AND ZVISHAVANE DISTRICTS

i. SMALLHOLDER FARMERS' RESPONDENTS BY GENDER

The study targeted both male and female smallholder farmers in the targeted districts. More female smallholder farmers participated in answering the household questionnaire in the study as compared to male. The overall proportion of female to male smallholder farmers participating in the study was 70 to 30 percent. Zvishavane district recorded higher female respondent's ratio with 82 percent compared to Chiredzi's 58 percent (Figure 4.1). Female participants were more in Zvishavane where most men migrate to other areas for artisanal mining.

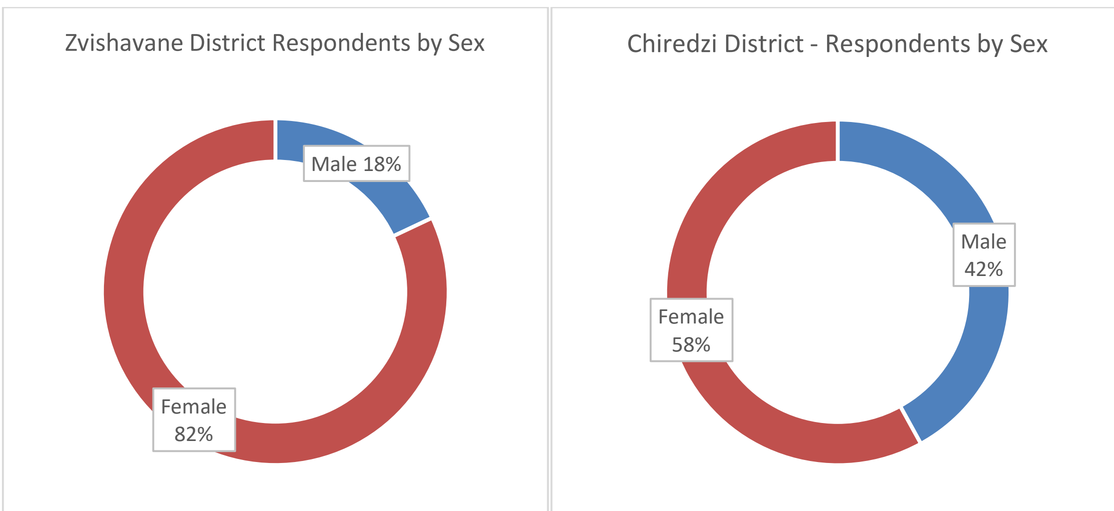

Figure 4.1 Smallholder farmer respondents by sex
***Source**: Author, 2021*

ii. SMALLHOLDER FARMERS BY AGE GROUPS

The results indicated participation by all active smallholder farmers' age groups in the research, and there was the deliberate exclusion of minors. Results indicated that the highest age group participated and dominated across the study areas recording 47 percent, while the lowest participated age group recorded 12 percent. In both districts, the age group 46-64 years dominated the study, followed by the age group 36-45 years. The study further revealed that the Zvishavane district had more participants from the age group 18-35 years with 18 percent compared to 12 percent of Chiredzi district participants within the same age group. Chiredzi district recorded the highest proportion of smallholder participants within the elderly (65+) age group. Figure 4.2 below presents the study respondents by age group.

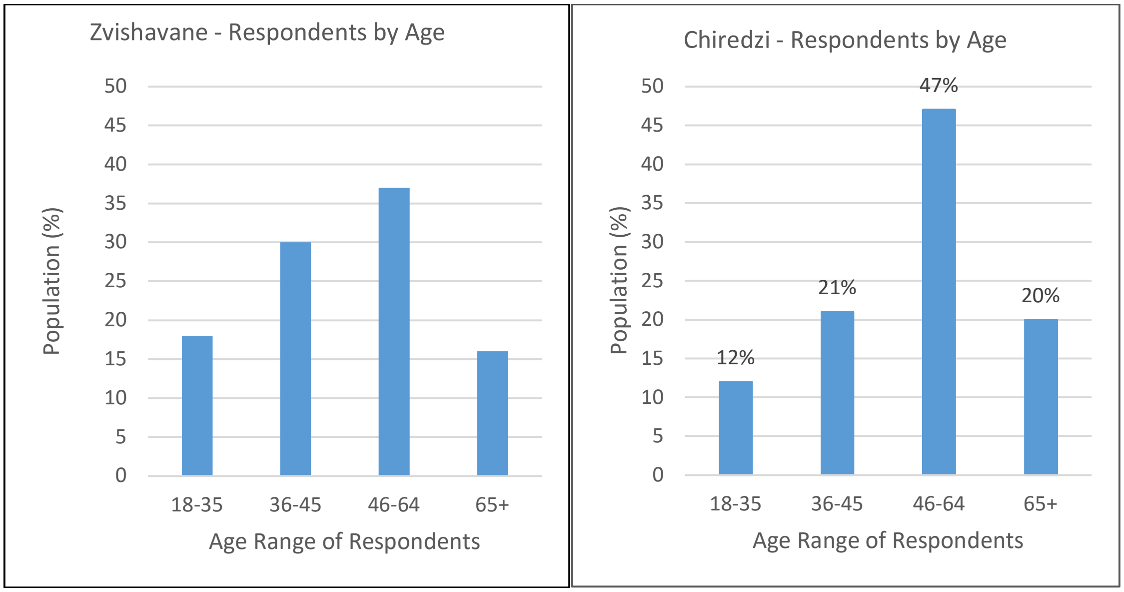

Figure 4.2 Smallholder farmers respondents by age group
Source*: Author, 2021*

iii. LAND TENURE IN CHIREDZI AND ZVISHAVANE SMALLHOLDER FARMING AREAS

In terms of the land tenurial system in the Chiredzi and Zvishavane districts, all smallholder farmers interviewed fall under one system, the Occupancy Right to Land in Communal Areas. The farmers who responded indicated their occupancy of an average of 2 hectares of land for crop production per household and a shared communally-owned grazing land. Furthermore, communally owned resources, including forests, water bodies, wells, springs, and other water points, are managed using existing local institutional arrangements.

iv. SMALLHOLDER FARMERS AND THEIR LENGTH OF STAY IN TARGETED COMMUNITIES

The study indicated that most participants stayed in the targeted areas for more than 30 years. Results indicated that smallholder farmers who stayed for more than 30 years were 56 percent from the Zvishavane district and 66% from the Chiredzi districts. The results indicated that the proportion of participants decreased with the decrease in the length of stay in the study areas. On average, 39% of farmer respondents stayed for 30 years or less, whilst 61% stayed for more than 30 years in the study area (Figure 4.3).

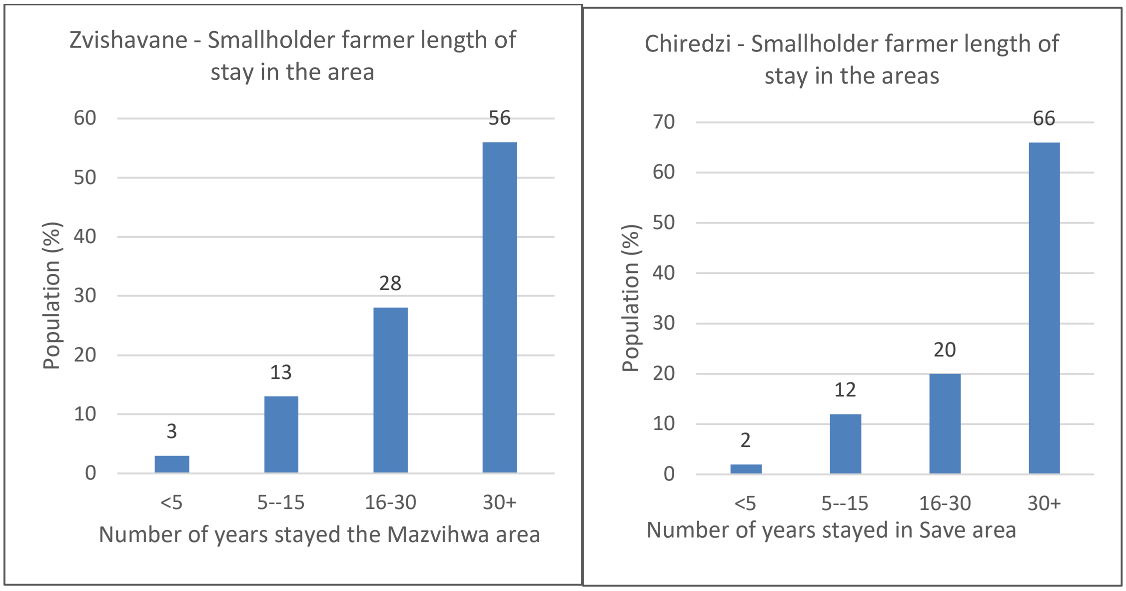

Figure 4.3 Smallholder farmer's length of stay in targeted communities
***Source**: Author, 2021*

v. SMALLHOLDER FARMERS' PERSPECTIVES ON CLIMATE CHANGE

The study was also interested in revealing smallholder farmers' context, perceptions and impacts resulting from climate change. Determining the respondents' perceptions was key in understanding farmers' lived experiences and knowledge levels on the impacts of the changing climate on water management. The findings indicated that all (100 percent) respondents knew about climate change and related impacts within their communities. Results further implied that the subject under study was topical, with every respondent having experienced climate change related impacts in one way or another. A female smallholder farmer from Plaaz 2 Village in Ward 17 of Zvishavane echoed the same sentiments during a focus group discussion and was quoted saying: *"Farmers no longer know when the growing seasons start or end. The onset and cessation of rainfall are no longer predictable. Early planting results in poor and failed germination due to soil moisture stress. Late planted crops have all wilted because the rains stopped earlier than expected. We have run out of ideas."* (ZHR66, January 2021)

The results also indicated that smallholder farmers had experienced a marked reduction in cereal crop yields. An agricultural lead farmer from the Chiredzi district pointed out during a focus group interview and said: *"I have experienced a continued decline in the yields of maize crops from around 500 kilograms per season to 300 kilograms at most over the past 20 years."* (CHR223, October 2020)

Results indicated that climate change impacts were experienced by all smallholder farmers, as indicated by their lived experiences, declining crop yields, droughts, and the unpredictability of the rainfall.

vi. CLIMATE CHANGE INFORMATION FOR SMALLHOLDER FARMERS

The research considered climate information as a critical resource required for building early warning and preparedness by the communities. The study results revealed that smallholder farmers in Chiredzi and Zvishavane districts utilize indigenous climate knowledge and scientific climate information systems, as detailed in the following section.

a) Scientific climate information

Results indicated that the sources of scientific climate information used in both districts were public media, government extension officers and non-governmental organizations (NGOs). The majority (61 percent) of the scientific climate information consumed by smallholder farmers is provided and disseminated by government extension officers and followed by the public media (28 percent). The remaining 11 percent was noted to be provided through the complementary role played by non-governmental organizations (Figure 4.4).

Public media channels, which included radio and television services, were identified in the study as the sources of scientific climate information generated by the Government of Zimbabwe's Meteorological Services Department. The district's Civil Protection Unit (CPU) used public media to disseminate scientific climate information to the community through elected councillors, the ward chairpersons for CPU, traditional leaders, and agricultural extension officers. Some wards had Disaster Risk Reduction (DRR) Committees that played a frontline role in climate disaster-related information dissemination to their respective communities. Results further indicated that government extension officers who provided scientific climate information were Agricultural Extension Services (AGRITEX) officers. The officers rolled out ward-based seasonal forecasts through community meetings, bulk short message services, and social media platforms (WhatsApp).

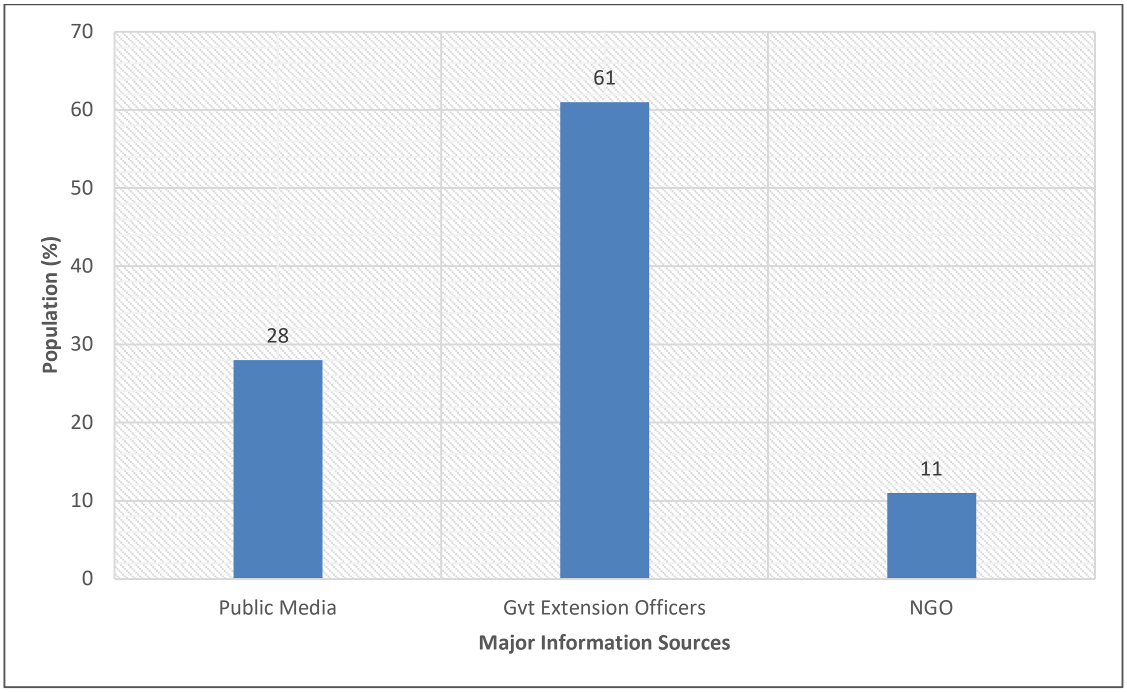

Figure 4.4 Sources of scientific climate information for smallholder farmers
Source*: Author, 2021*

b) Indigenous Knowledge Systems (IKS)

The study findings highlighted that all smallholder farmers interviewed had knowledge of the existence and utilization of some indigenous knowledge systems used to predict short-term seasonal climate forecasts. At ward level, the results indicated climate knowledge transfer mechanisms being facilitated by a specific group of elderly, traditional leaders, religious leaders, and experienced individuals. Information shared through indigenous knowledge systems on climate forecasting techniques in the targeted communities was not documented and depended on individual experience, area and the differences in biophysical triggers observed by foretellers. Results of the study revealed that the forecast given by indigenous knowledge systems was short to medium term. The results further indicated that the information from IKS was limited to weather and short-term seasonal outlook. Participants of the focus group discussions in Chiredzi and Zvishavane indicated that indigenous forecasts provided information on temperature changes, the "*guts*" scenario, short-term rainfall occurrence, prediction of cold and warm spells and drought season.

4.2.1.1 SMALLHOLDER WATER RESOURCES IN CHIREDZI AND ZVISHAVANE DISTRICTS

This section presented the study findings on water sources, their utilization, ownership, functionality, lifting device used and seasonal availability in the two districts of study. The findings revealed that water sources utilized by the communities were boreholes, wells/springs and rivers. The study participants mentioned that they used water for drinking, cleaning, irrigation, and livestock. The study further identified that water sources in the targeted communities were owned by communities (public owned), individuals and institutions. Results revealed that there was multiple water use in the two districts, with some water sources serving multiple purposes and others being dedicated to specific single uses.

Water sources, ownership, and utilization by smallholder farmers

The study findings have shown that borehole water use was very high in both districts, with 68 percent of the participants depending on the borehole water source. Twenty-three (23) percent of the participants revealed that they relied on wells, and 9 percent relied on water directly from the rivers (Figure 4.5).

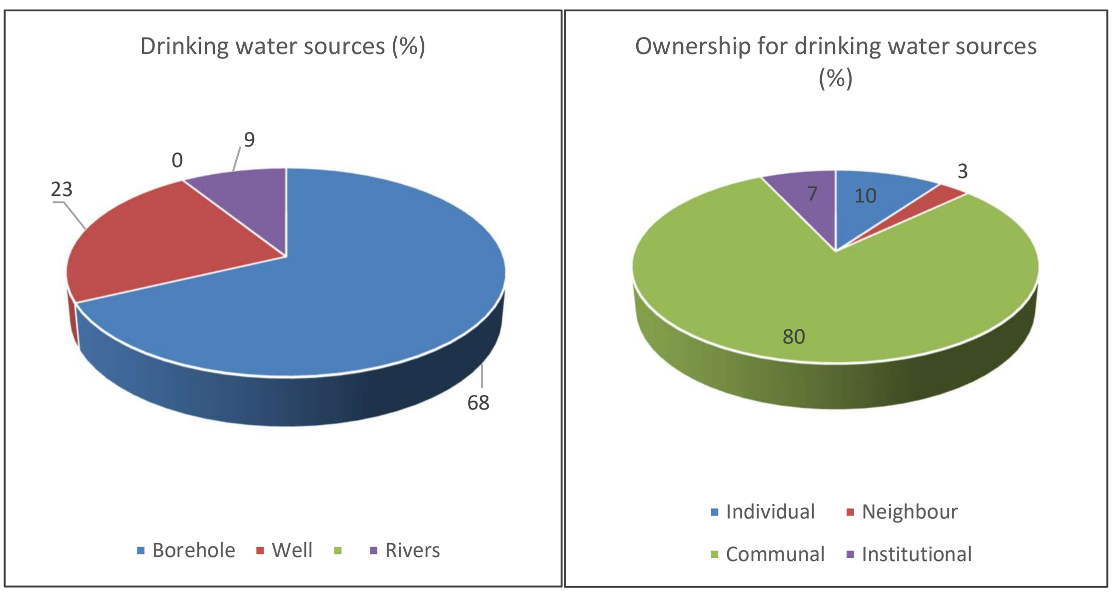

Figure 4.5 Drinking water sources and ownership
***Source**: Author, 2021*

The results indicated that 80 percent of drinking water sources were communally owned and managed. The public controls the communally owned water sources at the village and ward levels. These sources were developed by government, community, and development partners for community benefit. A proportion reaching 10 percent of drinking water sources was developed, owned, and managed at the individual household level using individual households' resources and efforts. A proportion of 7 percent of the participants reported that they depended on institutional water points. Institutional water points used by communities in Chiredzi and Zvishavane districts were those water sources developed and located at rural schools, clinics, and churches for institutional water needs. Development of water sources at individual smallholder household levels has been slow. Only 3 percent of the smallholder farmers depended on drinking water sources developed by neighbours. The KII and FGDs indicated that public sector development programmes mainly developed drinking water sources for the benefit of the community. Key programmes, including Rural Water and Sanitation Programmes funded by UNICEF, were implemented in Chiredzi and Zvishavane districts by government and development partners and increased borehole water development.

The study further investigated the existence of cleaning water sources and their ownership. Cleaning water considered in the study was that used for washing, bathing, and maintaining a hygienic environment. Figure 4.6 indicated that boreholes were utilized by 57 percent, rivers by 23 percent and wells by 20 percent of participants.

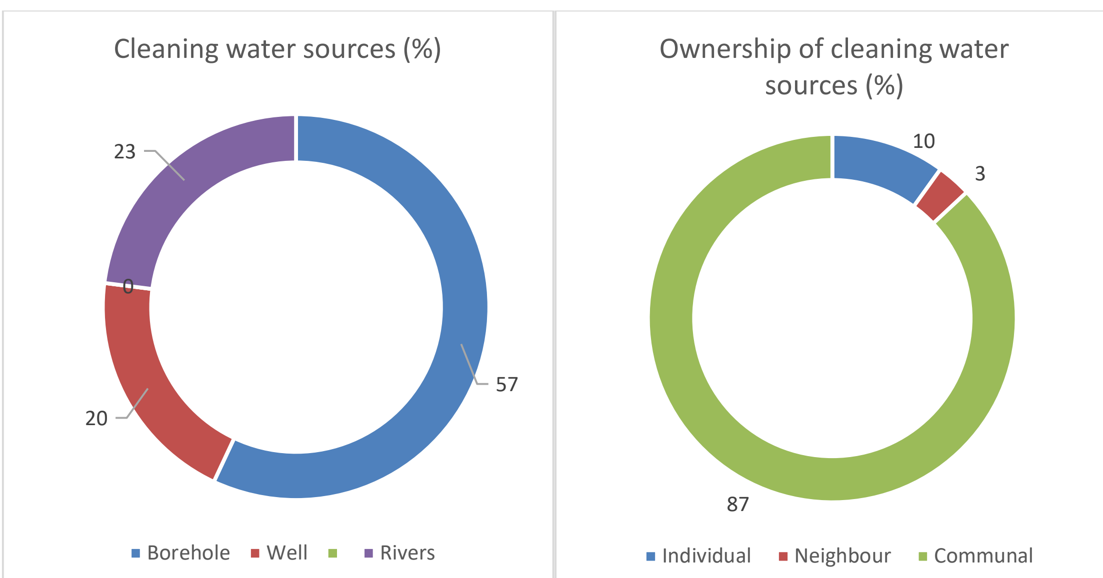

Figure 4.6 Cleaning water sources and ownership by smallholder farmers
***Source**: Author, 2021*

A total of 48 percent of irrigation water used by smallholder farmers in the two districts was from borehole sources. Rivers, dams, and wells contributed irrigation water with 26 percent, 19 percent and 7 percent, respectively (Figure 4.7). The findings indicated that the bulk of irrigation water (93 percent), was communally owned. Individual households collectively owned 7 percent of the total irrigation water sources in the Chiredzi and Zvishavane districts.

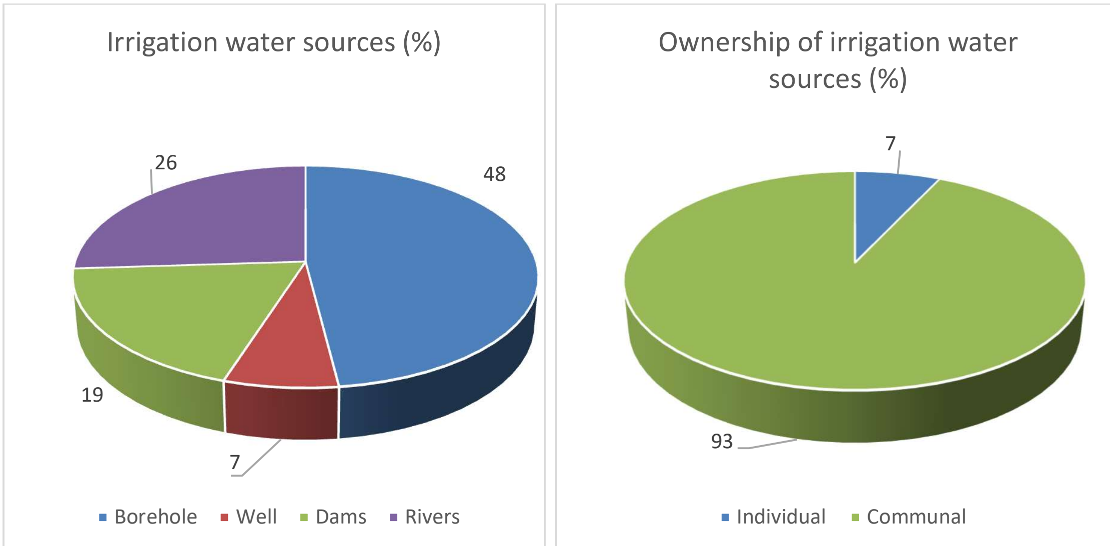

Figure 4.7 Irrigation water sources and ownership by smallholder farmers
Source*: Author, 2021*

It was revealed from the study that most communities in the dry lands of Chiredzi and Zvishavane districts owned livestock for their livelihoods and as a source of wealth. Water was identified as key in livestock rearing in dry communities targeted by the study. Figure 4.8 presents the utilization of water sources for livestock rearing and ownership.

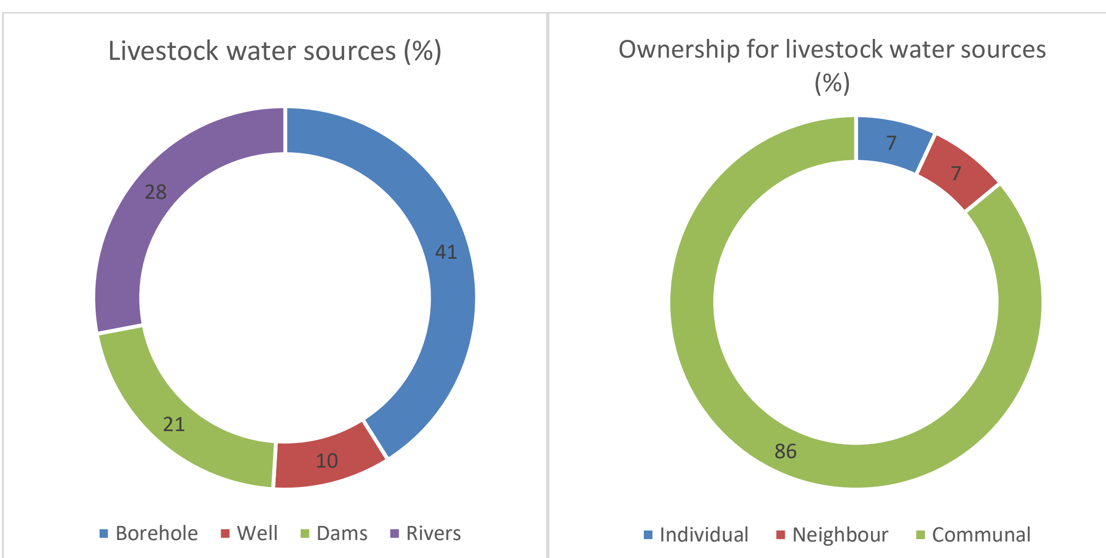

Figure 4.8 Livestock water sources and ownership
Source*: Author, 2021*

The study revealed that boreholes were the dominant source of livestock water used by 41 percent of the respondents. A proportion reaching 28 percent of livestock water sources was from the rivers, whilst dams contributed 21 percent. Groundwater sources (wells and springs) contributed 10 percent of livestock water in the two districts.

Data gathered through FGDs and KII further revealed a marked change in the flow pattern of the four rivers in the Chiredzi and Zvishavane districts. Smallholder farmers and key informants from the Chiredzi district indicated that Mkwasine and Save Rivers used to be the significant sources of livestock water in the past good rainfall years. Communities in Zvishavane revealed that Runde and Gwemombe Rivers used to be perennial livestock water sources. Indications from the study pointed to a change in the flow of river patterns in line with the reported reduced rainfall amounts that affected surface water availability throughout the year.

Water source functionality

The study's findings revealed that different water sources in the Zvishavane district (Table 4.1) and Chiredzi district (Table 4.2) had different states of functionality ranging from fully functional, partially functional, collapsed, and not functional. The functionality of water sources in the study areas was primarily linked to infrastructure management, water availability, conservation, the durability of materials, hydrogeological formation, and pressure exerted on water points due to different competing uses.

Table 4.1 Water source functionality in the Zvishavane district

Zvishavane District - Water Sources Functionality					**Total**
Water Source	**Fully Functional**	**Partially Functional**	**Collapsed**	**Not Functional**	
Borehole	332	61	29	66	**488**
Dams	19	3	1	0	**23**
Deep Wells	22	14	3	20	**59**
Shallow Wells	47	90	5	23	**165**
Springs	13	1	0	0	**14**
Sand Abstraction	7	17	2	1	**27**
Rainwater Harvesting	7	7	0	2	**16**
Total	**447**	**193**	**40**	**112**	**792**

***Source**: Author, 2021*

Results from the Zvishavane district indicated that out of 792 different water points identified, 56.4 percent (447) were fully functional. A proportion of 24.4 percent (193 water points), 5.1 percent (40 water points), and 14.1 percent (112 water points) were reported to be partially functional, collapsed and not functional, respectively (Table 4.1). Out of 1327 water points identified by the study in the Chiredzi district, 45.7 percent (607) were fully functional. A proportion reaching 17.3 percent (229), 13.3 percent (177) and 32.7 percent (314) being partially functional, collapsed and not functional, respectively (Table 4.2).

Table 4.2 Water source functionality in the Chiredzi district

Chiredzi - District - Water Sources Functionality					Total
Water Source	**Fully Functional**	**Partially Functional**	**Collapsed**	**Not Functional**	
Borehole	431	161	159	242	993
Dams	9	2	1	3	15
Deep Wells	128	43	15	52	238
Shallow Wells	27	17	2	7	53
Springs	2	1	0	2	5
Sand Abstraction	8	4	0	7	19
Rainwater Harvesting	2	1	0	1	4
Total	**607**	**229**	**177**	**314**	**1327**

Source*: Author, 2021*

The study revealed that boreholes constituted the bulk of water sources, and their functionality was based on various factors irrespective of location, time of development and use. In the Zvishavane district, the results indicated that the oldest functional borehole was developed in 1930, and the newest in 2021. Chiredzi district had two oldest fully functional boreholes constructed in 1936 and 1948, but the newest fully functional was developed in 2021. It was an exciting finding that the newest collapsed boreholes were developed in 2014 for both districts, while the oldest collapsed boreholes were constructed in 1936 and 1942 for Chiredzi and Zvishavane districts, respectively. Participants of the focus group discussions buttressed the point that water source functionality was based on various factors, with the management aspect and durability of infrastructure developed being the main pillars.

The study assessed the functionality of 59 and 238 deep wells in the districts under study. Out of these, Zvishavane had 22 fully functional, 14 partially functional, three collapsed and 20 not functional, while Chiredzi district's 128 were fully functional, 43 were partially functional, 15 collapsed and 52 not functional. The oldest functional deep well for Zvishavane was constructed in 1927, while for Chiredzi was constructed in 1948. Furthermore, springs were identified as traditional and culturally protected sources of water that were developed, conserved, and passed on from one generation to the other.

Focus group discussions and field observations results identified the existence of 5 springs in Chiredzi and 14 springs in the Zvishavane district. Out of these identified springs, only two were fully functional in Chiredzi district, while Zvishavane district recorded 13 fully functional. Jumela and Mutakura springs in Zvishavane district's ward 17 were developed in 1940 and 1954, respectively and continued to provide water for the community. Chiredzi district's Ndali spring was protected since 1930 and was fully functional, providing water to 249 households. Results indicated that Mubhinyi and Chingoji perennial springs in Chiredzi had been protected since 1972 and supplied water to 92 and 10 households, respectively. The results from focus group discussions in both districts indicated that springs and deep wells technologies were developed and sustained over time as an essential water source.

The study identified sand abstraction techniques as crucial sources of gardening and domestic and livestock water supply for many households in the study area. These water sources were concentrated in Nyangambe, Musvisvizi, Muonde and Chiwanje areas along Mkwasine and Save Rivers. In the Zvishavane district, Muringi and Kufandada communities in ward 16 reported that they depended on Runde River sand abstraction water during the dry season. In the Chiredzi district, a focus group discussion at Dendere irrigation revealed that the communities depended much on sand abstractions.

The study assessed 16 and 4 rainwater harvesting systems in Zvishavane (Table 4.1) and Chiredzi (Table 4.2) districts. The study identified rainwater harvesting activities as complementary water sources used by communities in both districts during the rainy season. In the Zvishavane study area, rainwater harvesting was identified in wards 16 and 17 and practised mainly at the household level. The study further identified rainwater harvesting systems in the Chiredzi district developed at Mugiviza Primary School in 2005, Mwenje Primary school in 2015, Mupinga Primary School in 1995, and Muteyo clinic in 2009. The assessment results indicated that all rainwater harvesting used rooftop techniques (roof catchments) and was only functional during rain events.

Water lifting device / Technology Functionality

The research assessed different water lifting devices used on boreholes and wells only in both districts. Bush pump type A, bush pump type B, elephant pump, mono pump, national pump, and electric submersible pump were identified to be in use on various water points, as presented in tables 4.3 and 4.4. Results indicated that the most common type of lifting device or technology was hand pump technology, the bush pump type B. Government extension services and MGO/CBOs informants indicated that the adoption of bush pump type B was high and promoted by policy, phasing out the bush pump type A.

Table 4.3 Water lifting device/Technology Functionality in Zvishavane District

Water Pumping / Lifting Device	**Zvishavane District**				**Total**
	Fully Functional	**Partially Functional**	**Collapsed**	**Not Functional**	
Bush Pump Type A	2	2	4	2	**10**
Bush Pump type B	302	58	22	62	**444**
Elephant Pump	1	0	0	0	**1**
Mono Pump	3	0	3	1	**7**
National Pump	2	0	0	0	**2**
Submersible Solar Pumps	19	1	0	1	**21**
Total	**329**	**61**	**29**	**66**	

***Source**: Author, 2021*

The study revealed that in the Zvishavane district, 68 percent (302) of the bush pump type B were fully functional, 13.1 percent (58) were partially functional, 5 percent (22) were collapsed, and 14 percent (62) were not functional. In comparison, in the Chiredzi district, 42.8 percent (383), 17.1 percent (153), 15.9 percent (142) and 24.3 percent (218) were identified as fully functional, partially functional, collapsed and not functional, respectively.

Table 4.4 Water lifting device/Technology Functionality in Chiredzi District

Water Pumping / Lifting Device	**Chiredzi District**				**Total**
	Fully Functional	Partially Functional	Collapsed	Not Functional	
Bush Pump Type A	1	0	13	4	**18**
Bush Pump type B	383	153	142	218	**896**
Mono Pump	9	0	2	3	**14**
National Pump	2	0	0	0	**2**
Submersible Solar Pumps	37	7	2	7	**53**
Total	**432**	**160**	**159**	**232**	

***Source**: Author, 2021*

Participants of the Mazvihwa FGD community in Zvishavane district, Mupinga community in the Chiredzi district, and pump minders revealed that the functionality of water pumping or lifting devices was largely dependent on equipment durability, management, operation, and maintenance aspects. Results from both districts further indicated that elephant pumps, mono pumps and national pumps' adoption and utilization rates were on the lower side for both districts. The study indicated that all the national pumps installed in both districts were fully functional and located at institutions. The results further identified the use of submersible solar pumps as the second most adopted lifting device, with 90.5 percent (19) out of 21 in the Zvishavane district and 70 percent (37) out of 53 assessed in the Chiredzi district being fully functional.

Seasonality of smallholder water sources

The findings from the study indicated that seasonality of water sources in Chiredzi (Figure 4.9) and Zvishavane (Figure 4.10) districts depended on the type of water sources, rainfall recharge, depth of groundwater sources, management practice and aquifer yields. During a focus group discussion, one female irrigator at the Dendere irrigation scheme in the Gudo area of Chiredzi was quoted saying, *"The rains are too little and cannot fully replenish our water systems."*

The study revealed that boreholes, wells, and springs had perennial and intermittent water points in both Chiredzi and Zvishavane districts. Between 81 and 70 percent of all groundwater-dependent sources in Chiredzi are perennial, indicating the greater potential for groundwater aquifers in supporting smallholder farmers. Sand abstraction and rainwater harvesting techniques were identified in both districts as intermittent sources of water. Surface water-dependent sources, including sand abstraction and rainwater harvesting, were all seasonal because the former depends on riverbeds through flow while the latter depends on direct rainfall. The two sources of water harvesting were used during different seasons. The assessment indicated that groundwater sources in the Chiredzi district were more perennial than surface water sources. The proportion of perennial boreholes, deep wells, shallow wells, and springs was higher at 81 percent, 77 percent, 70 percent, and 80 percent, as compared to the intermittent proportion that was 19 percent, 23 percent, 30 percent, and 20 percent respectively (Figure 4.9).

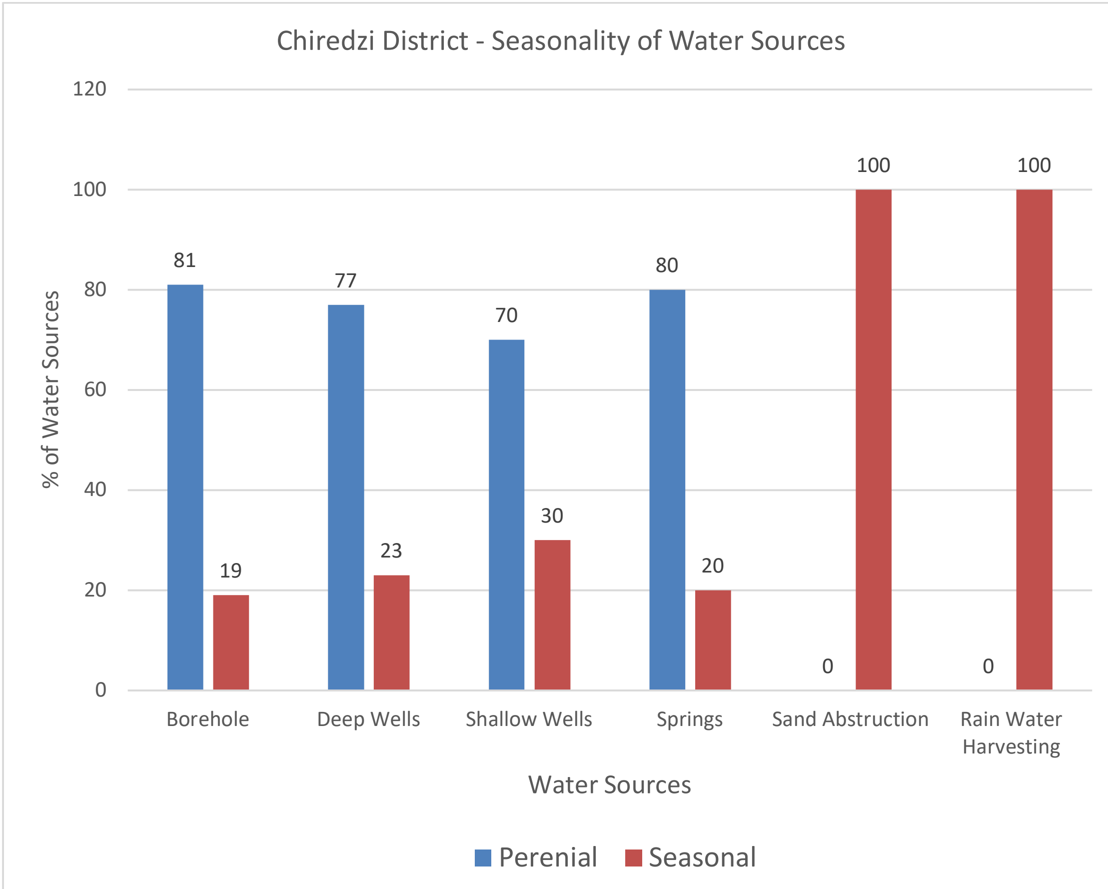

Figure 4.9 Seasonality of water sources in the Chiredzi district
Source: *Author, 2021*

Assessments of the hydrogeological formations in different selected locations in Chiredzi indicated the existence of a combination of deep-seated, high, and low-yielding aquifers. Results from the Ndali community revealed the existence of a large productive aquifer on the point marked A and a solar-powered borehole developed at point marked B1 (Figure 4.10).

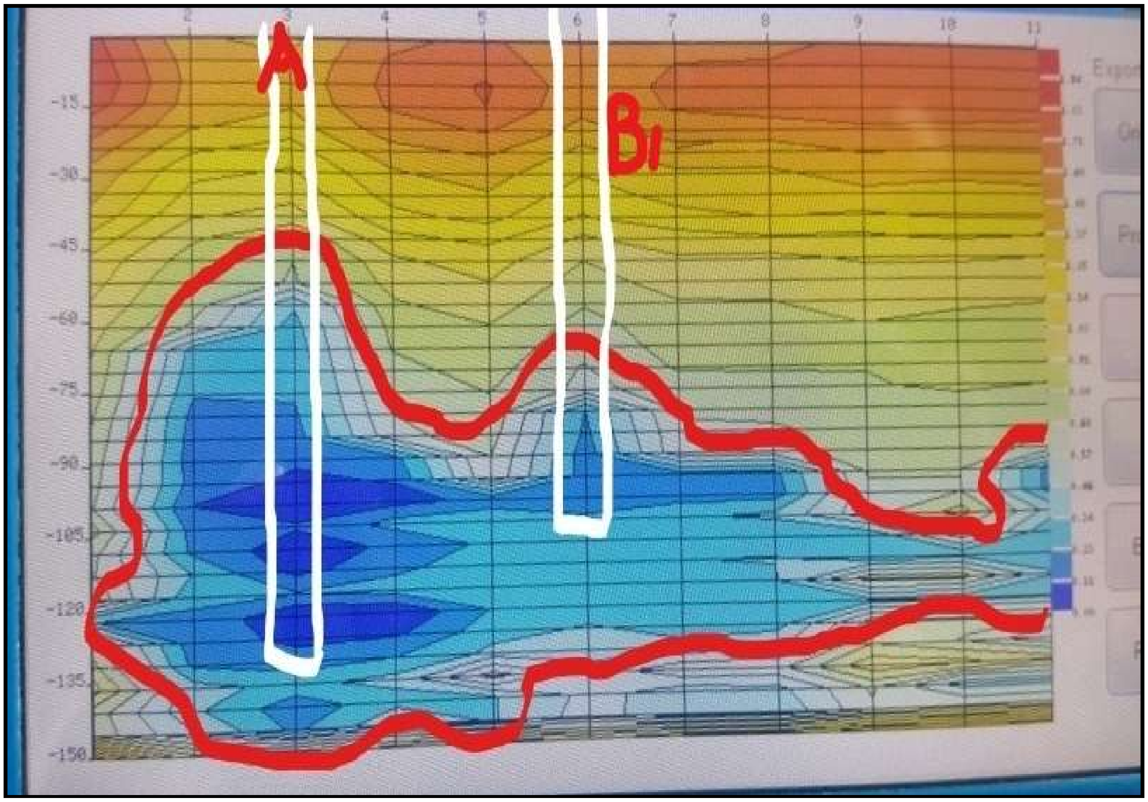

Figure 4.10 Hydrogeology and groundwater aquifer for Ndali, Chiredzi district
***Source**: Author, September 2020*

Direct measurements and field observations revealed that the borehole was developed on the shallow side of the aquifer at point B1 (Figure 4.10) instead of a highly productive point A. This supported the reason behind the seasonality and low yielding of some boreholes in Chiredzi district. The key informants from DDF indicated that a key element for water sources sustainability was technical capacity in the development of water sources.

In Zvishavane district (Figure 4.11), the results indicated that the proportion of perennial boreholes, deep wells, shallow wells, and springs was 71%, 34%, 18%, and 69%, respectively as compared to the intermittent proportion that was 29%, 66%, 82%, and 31% respectively. The findings of the hydro-geophysical measurements further indicated that for Zvishavane district, the potential of getting perennial water is partly related to the depth of the source, with a low potential for shallow groundwater sources and a high potential for deep sources (Figure 4.11).

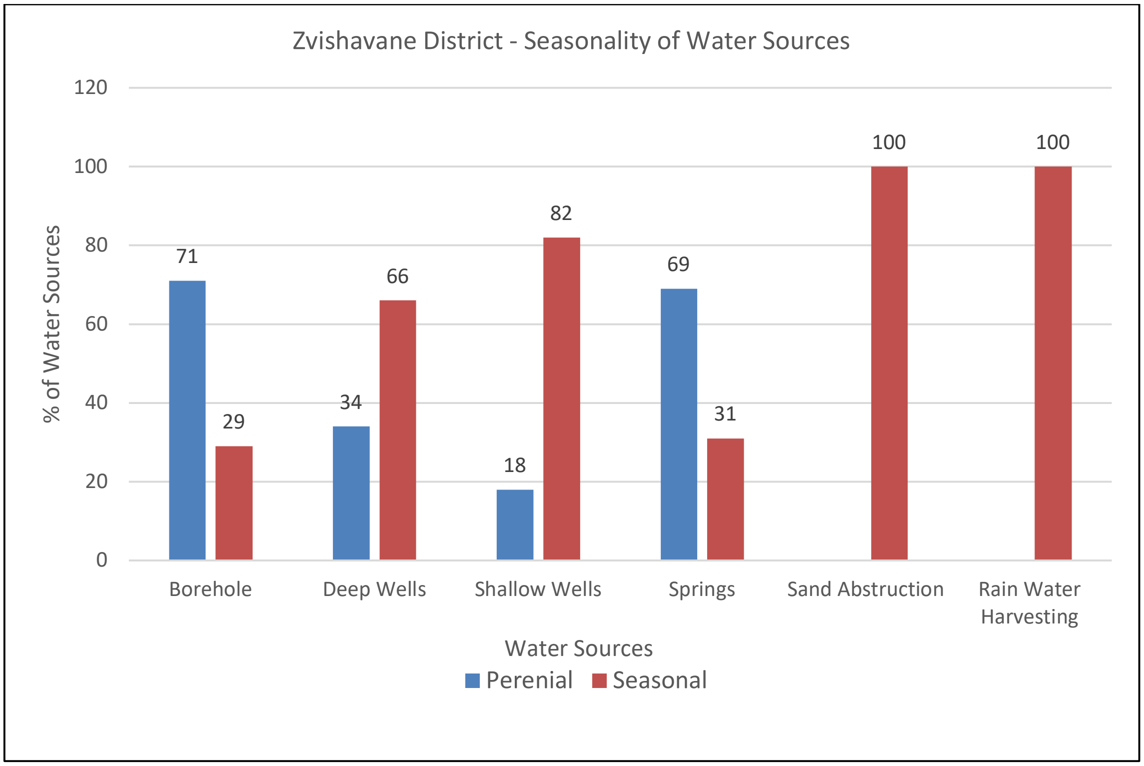

Figure 4.11 Seasonality of water sources in the Zvishavane district
Source*: Author, 2021*

The study indicated that the Zvishavane district had a lower percentage of perennial deep and shallow wells, with 34 percent and 18 percent, respectively. In comparison, the proportion of intermittent deep and shallow wells was higher at 66 percent and 82 percent, respectively. A comparison of the results from Zvishavane and Chiredzi indicated that 77 percent of deep wells and 70 percent of shallow wells in Chiredzi are perennial, whilst the remaining 23 percent and 30 percent of deep and shallow wells are seasonal, respectively.

Further analysis of the hydrogeological formation using direct measurements and field observations in the Zvishavane district (Figure 4.12) indicated a very small and low potential, yielding aquifer. The results indicated that the Timba borehole was developed at point A (Figure 4.1), which indicated a shallow aquifer with a low weathered zone. During the dry season, the Timba borehole provides the community with less water than during the rainy season. This scenario, informed by the measurements, helped to explain the reason behind more seasonal than perennial groundwater sources in the Zvishavane district that has an underlying low-yielding and low-productive aquifer.

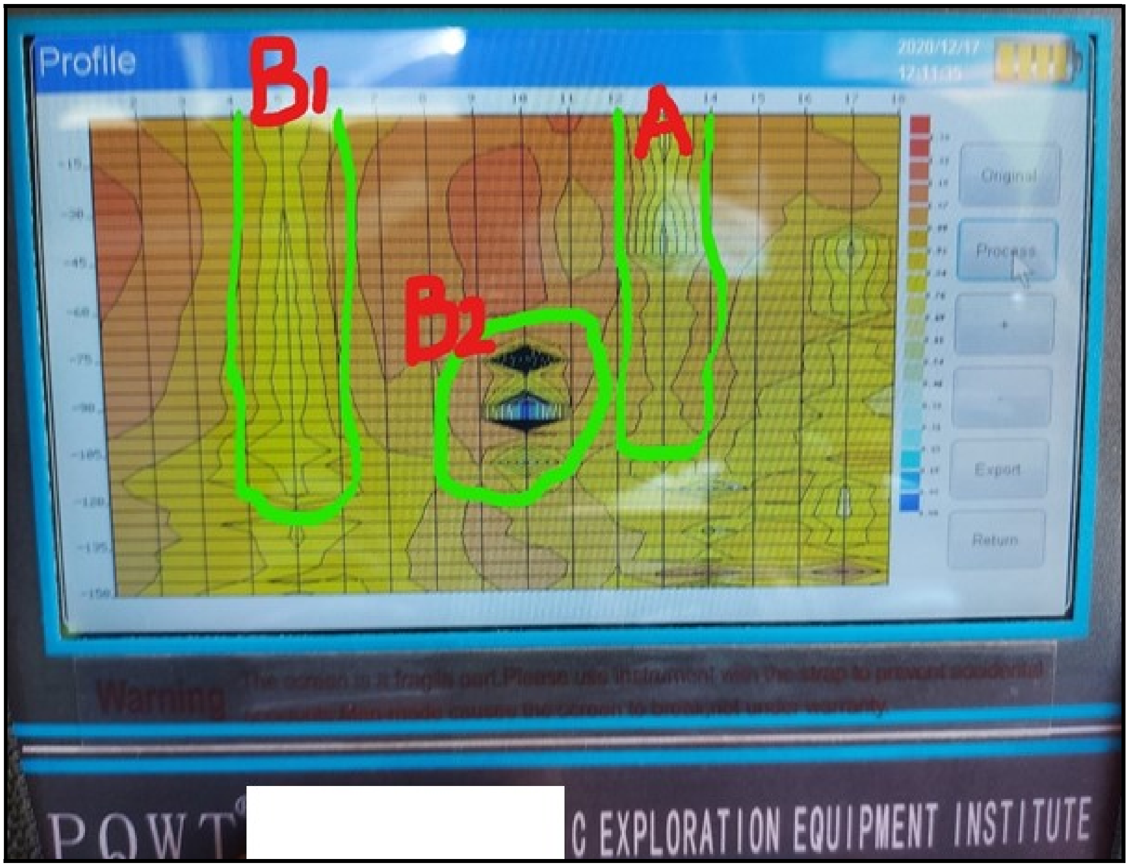

Figure 4.12 Timba hydrogeology and groundwater aquifer in Zvishavane.
Source*: Author, December 2020*

In both Zvishavane and Chiredzi districts, findings from FGDs, KIIs and field observations indicated that tracking distance for livestock and walking distance for people to water sources increases during the dry season. The study revealed that women walked from 2 kilometres in Chiredzi to 7 kilometres in Zvishavane, searching for clean domestic water when seasonal water points are dry. A general finding indicated groundwater is the primary sustainable source compared to surface and other water sources.

4.2.2 CLIMATE CHANGE-RELATED CONSTRAINTS FOR SMALLHOLDER WATER MANAGEMENT

The occurrence of climate-related natural shocks and hazards was noted to be increasing in targeted districts. Results further indicated that smallholder farmers' water resources and related socio-economic activities have been vulnerable to climate-induced shocks. Smallholder farmers respondents of the questionnaire survey noted temperature rise, rainfall pattern changes and the increase in drought events as key shocks and hazards. The increase in the occurrences of natural shocks and hazards was reported by 90% of the smallholder farmers. Respectively, 7%, 3%, and 0% of the questionnaire survey respondents indicated that the occurrence of these natural shocks and hazards was varying, decreasing, and not changing (Figure 4.13).

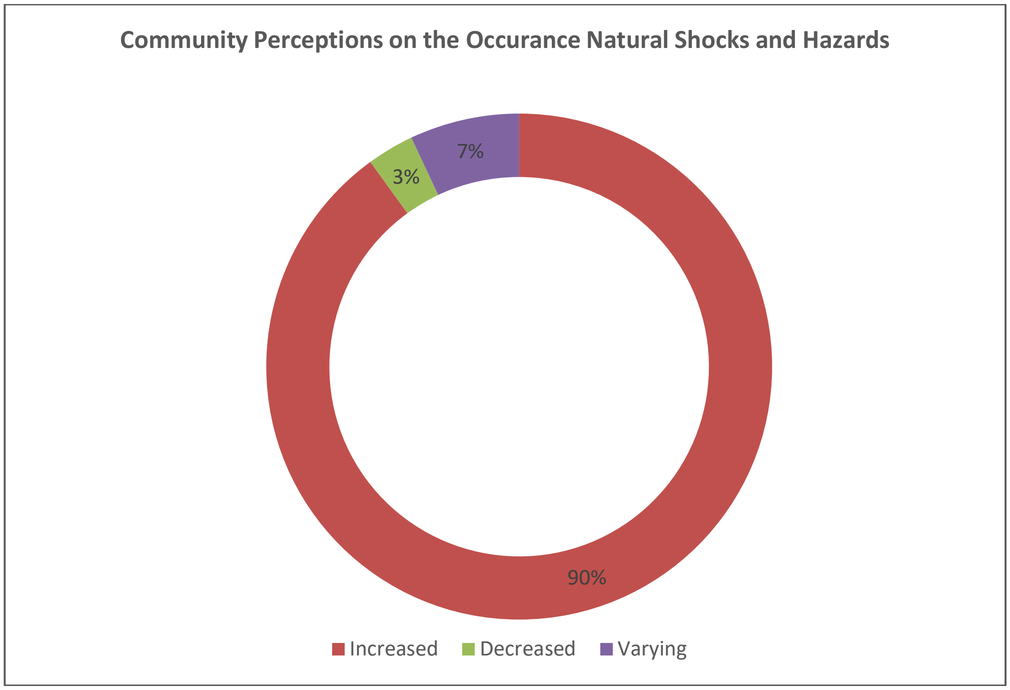

Figure 4.13 Community perceptions on the occurrence of natural shocks and hazards
Source*: Author, 2021*

Testimonials from FGDs in Chiredzi district revealed that communities were already experiencing negative climate change related impacts. One female participant from Hama village in Chiredzi district commented: *"Since 2000, our crop yields have been greatly reduced due to water scarcity. For survival, the community is venturing in various untraditional livelihoods coping strategies."* (CHR07, September 2020)

Reduction in agricultural production in the Chiredzi district was also testified by a male smallholder farmer from the Mashulani area who participated in the study and commented: *"We used to rear large herds of cattle, which were our households' savings and collateral. Because of serious recurrent droughts, livestock diseases and deaths, we lost more than half and are now broke."* (CHR22, October 2020)

The experiences of the smallholder farmers from Hama and Mashulani villages in the Chiredzi district were echoed by irrigation management committees, water point committees and dip tank committees, who pointed out that the increase in temperature and reduced rainfall amounted to affected crop yields, livestock and resulted in conflicts at water points. Conflicts at water points due to limited water availability were also noted in the Zvishavane district. The researcher had an opportunity to attend a conflict resolution meeting convened by DDF and Runde Rural District Council at Timba borehole in Murowa ward on the 14th of November 2020. The resolution was passed that the aquifer supplying the community borehole was low yielding. The following were the key outcomes of the conflict resolution meeting:

i. The challenge of water shortage was not artificial as supposed but a hydrogeological constraint.
ii. The water table became low, and the aquifer yield was very low in the dry season after the area received low rainfall that failed to replenish the groundwater.
iii. Water demand management strategies were proposed to be the solution to manage the few available resources.
iv. With the support of technical expertise and traditional leaders, the water point committee was empowered to fully implement the operation and maintenance of the solar pumping system.
v. Depending on the seasonal performance of the rainfall that replenishes the borehole, seasonal water management practices were recommended for enforcement to conserve and prioritize drinking water.
vi. To improve water management, documentation of yield monitoring for the borehole was recommended.
vii. A revolving water point fund was recommended to be put in place for use to cover the future and unplanned breakdown and maintenance costs.

i. GENERAL INCREASE IN TEMPERATURES

Temperature rise was noted as a main challenge experienced by smallholder farmers in the Chiredzi and Zvishavane districts. It was evident from the research results that smallholder farmers were failing to cope with the unusually high temperatures. Out of the 374 smallholder farmers interviewed, 97 percent of the respondents from all the districts indicated that temperature increase was a phenomenon they struggled to cope with (Figure 4.14).

Results from Chiredzi revealed cases of negative experiences brought by the rise in temperature to smallholder farmers. A participant from a focus group discussion with the ward-based DRR Committee was quoted commenting that: *"We have it in our memories and records that on the 25th of November 2011, the daytime temperatures rose to 49 degrees Celsius in this Save area and resulted in the deaths of birds and animals."* (CCWM04, October 2020)

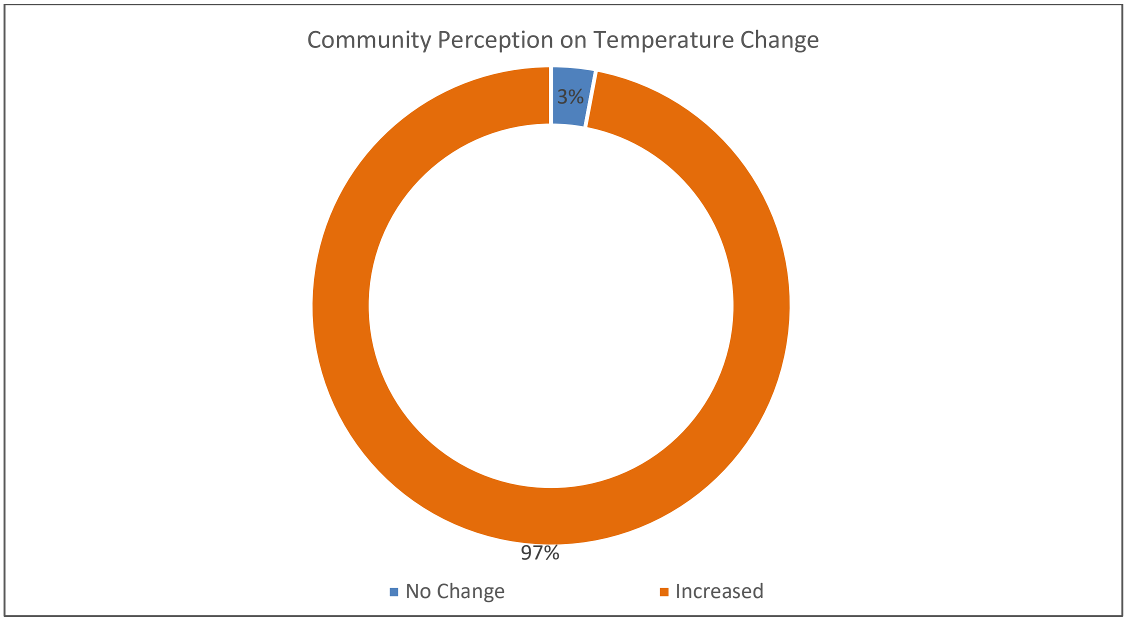

Figure 4.14 Community perception of Temperature increase
***Source**: Author, 2021*

An increase in irrigation, domestic and livestock water requirements was reported in all the districts. Smallholder farmers in Chiredzi and Zvishavane districts shared the same perception that temperature increased over the past 30 years. None of the smallholder farmers responded that they experienced a decrease or variation in the area's temperature. This further supports the findings on temperature rising across the districts and explains the emergence of new crop pests and animal diseases reported by smallholder farmers. The lived experienced and perceptions shared by farmers was further supported by Mann-Kendall (M-K) statistical test at $\alpha = 0.05$.

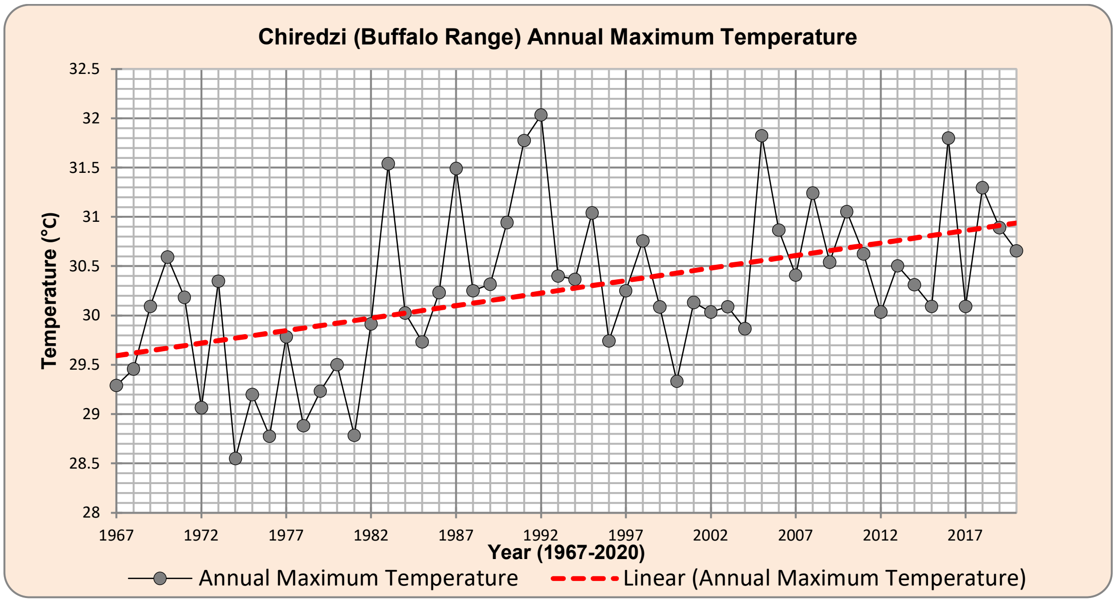

Figure 4.15 Chiredzi (Buffalo Range) Annual Maximum Temperature.
Source*: Author, 2021*

The statistical results from the M-K test for Chiredzi Buffalo Range (Figure 4.15) and Zvishavane Brange (Figure 4.16) temperature data showed a rising temperature trend over the past 54 and 58 years of analysis, respectively, with both p-values = 0.000. The mean temperature for the Chiredzi district over the period analysed using the M-K test was 30.27 degrees Celsius, while the standard deviation was 0.824.

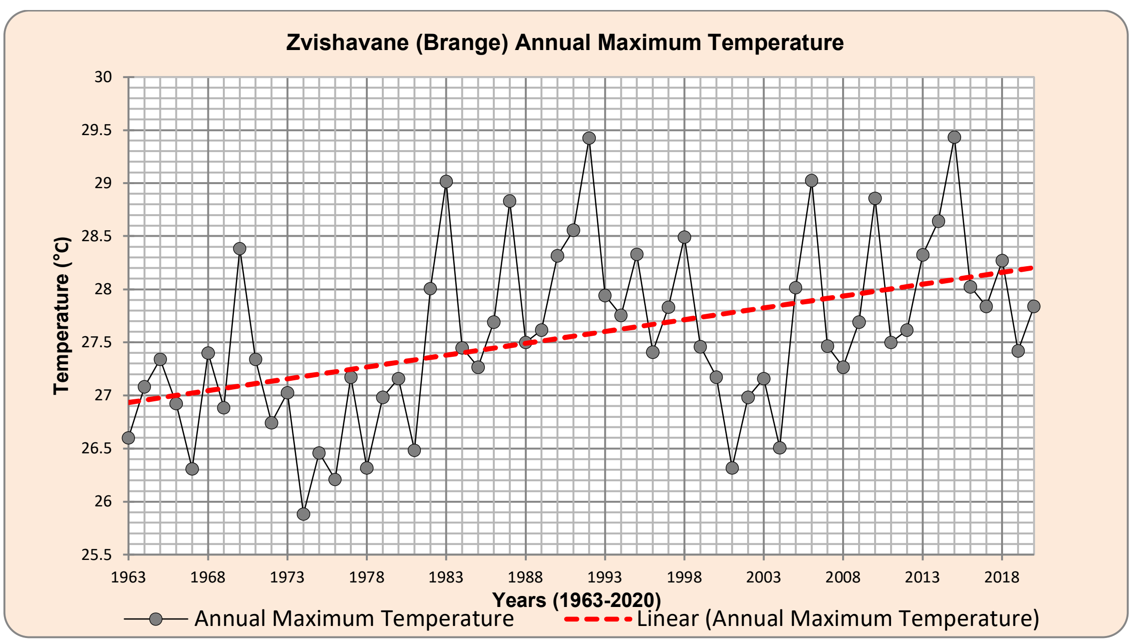

Figure 4.16 Zvishavane (Brange) Annual Maximum Temperature.
Source*: Author, 2021*

Statistical results of the Zvishavane district also concurred with community perceptions and experience that the temperature was increasing. Over the past 58 years, the mean temperature for the district was 27.57 degrees Celsius, with a standard deviation was 0.827. The comparison between Chiredzi and Zvishavane districts against the national temperature trend (Figure 4.17) confirmed smallholder farmers' perceptions and lived experiences in Chiredzi and Zvishavane. The national mean temperature was slightly lower than both districts at 26.95 degrees Celsius, and the standard deviation was 0.782.

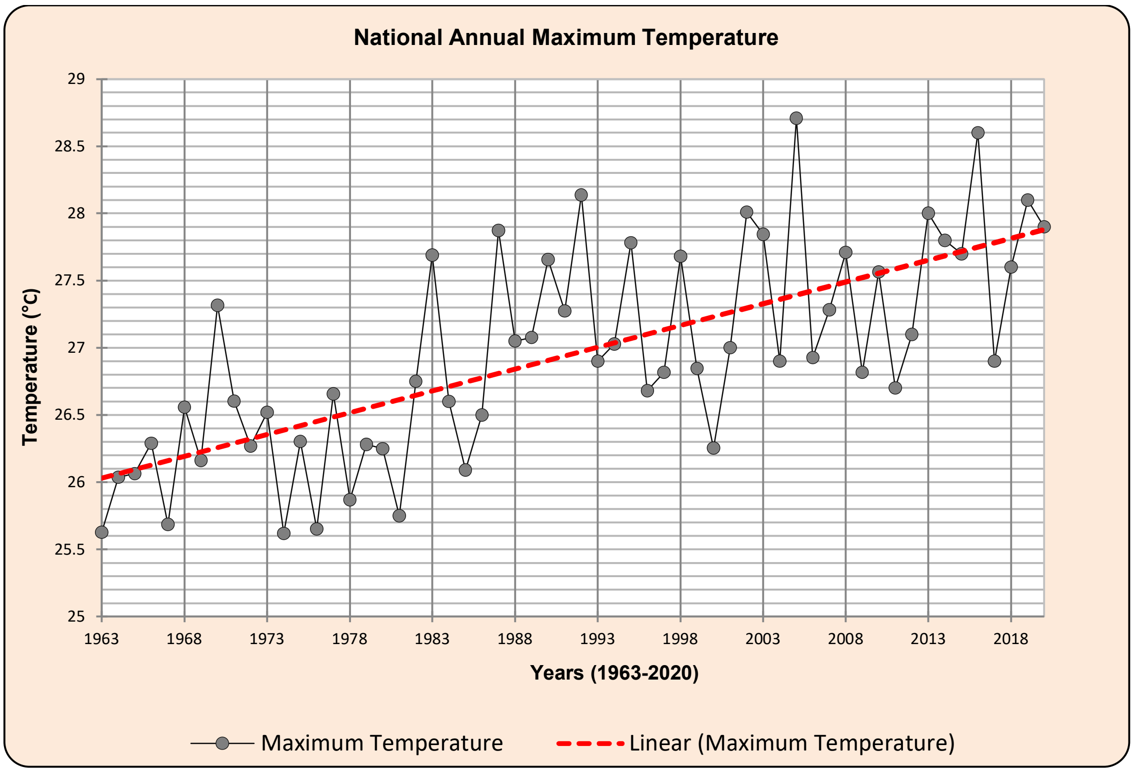

Figure 4.17 Zimbabwe Annual Maximum Temperature.
***Source**: Author, 2021*

The rising temperatures noted by the study over the years from smallholder farmers' perceptions, lived experiences and statistical analysis of historic data pointed out the climate change scenario taking place and affecting communities in Chiredzi and Zvishavane districts.

ii. CHANGE IN RAINFALL PATTERN / RAINFALL VARIABILITY

The study noted distribution, onset, and offset changes in rainfall patterns. Changes in length of the growing season, and the severity of mid-season dry spells as key rainfall-related constraints affecting Chiredzi and Zvishavane smallholder farmers. The study assessed the community perceptions and gathered the participants' views on changes in the total annual rainfall (Figure 4.18). Results indicated that 73% of the participants believed in the declining total annual rainfall over the past 30 years. Contrary to the majority views and perceptions, 23% and 4% of 374 smallholder farmers interviewed indicated that rainfall was increasing and highly variable, respectively (Figure 4.18).

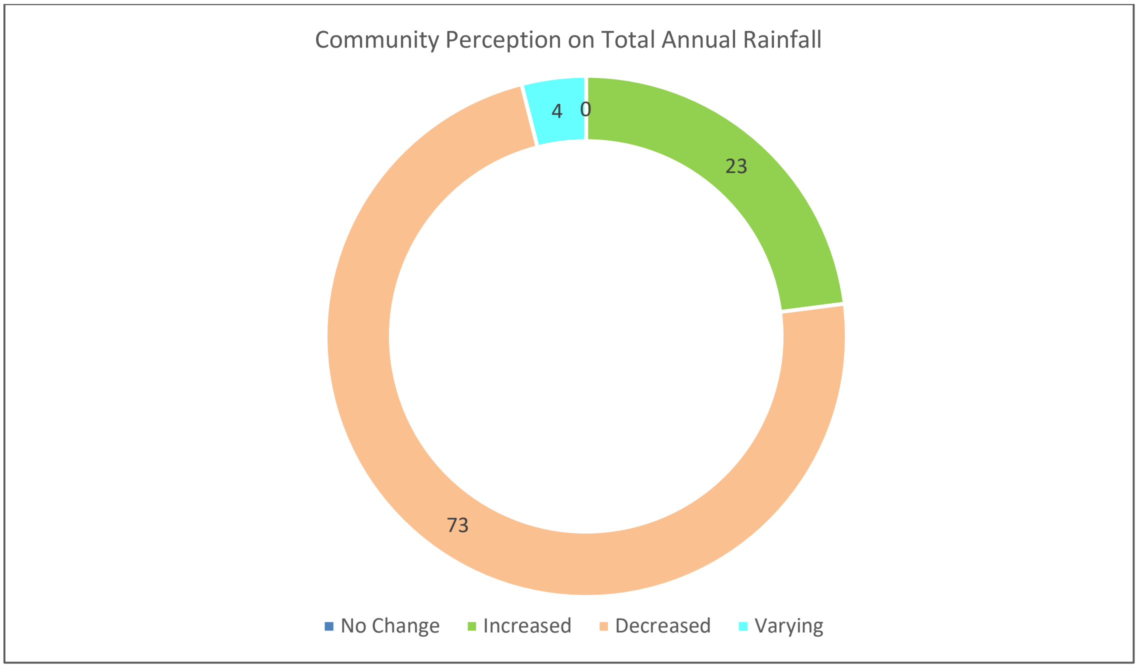

Figure 4.18 Community perceptions on total annual rainfall
Source*: Author, 2021*

All participants concurred that there were changes in annual rainfall occurrence. This was evidenced by the zero (0) percent proportion of smallholder farmers (Figure 4.18) who indicated that rainfall was not changing. From the FGDs, Chiredzi's Muteyo and Zvishavane's Mazvihwa community unanimously agreed that the growing season was shrinking, becoming shorter, as associated with rainfall late-onset and early cessation. A female lead farmer from the Muteyo community garden commented that:

"Over the past decades, rainfall started in October during normal rainfall season and ended in April of the following year. We had many consecutive years when we received rainfall in late January, which resulted in crop failure and livestock deaths due to water shortages. We are facing difficulties in planning, making agriculture a high-risk and unprofitable enterprise, especially for farmers without irrigation infrastructure." (CHR83, October 2020)

Whilst most smallholder farmers indicated experience with decreasing rainfall trend, the study findings revealed that the 23 percent of smallholder farmers who pointed out an increasing rainfall trend had memories of cyclonic events that resulted in flooding events, including cyclonic IDAI.

The study further analyzed historical rainfall data for the Chiredzi district (Figure 4.19) and Zvishavane district (Figure 4.20) in comparison to the national rainfall trend (Figure 4.21). The statistical test (*Mann- Kendall trend test*) applied was a two-tailed test with α = 0.05 for all the districts and national level.

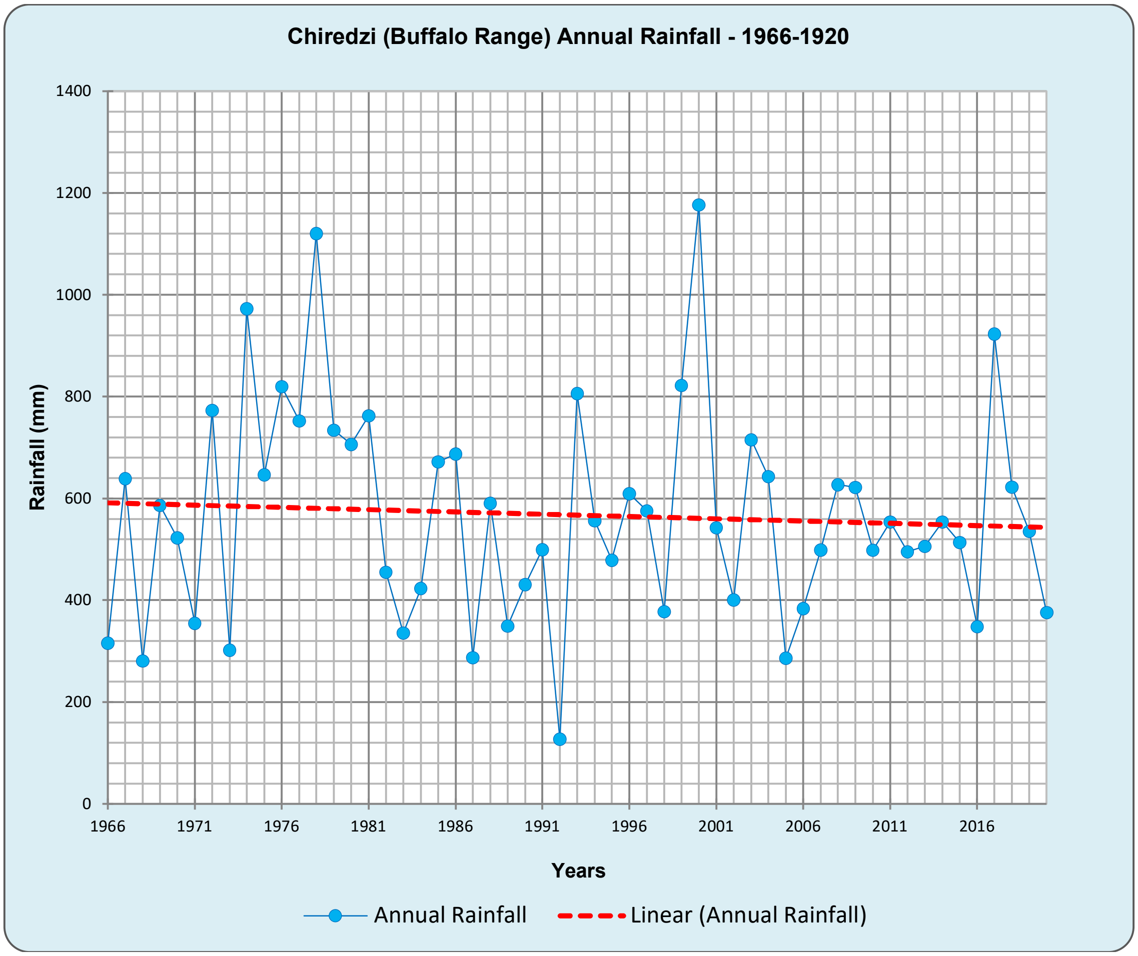

Figure 4.19 Chiredzi (Buffalo Range) Annual Rainfall Trends.
Source*: Author, 2021*

The statistical results from the M-K trend test for the Chiredzi district's 55 years of rainfall analysis indicated that the decline noted by smallholder farmers was not statistically significant since p-value (0.532) was great than α (0.05). Results from the Zvishavane district also confirmed the statistical insignificance of the smallholder farmers' declining rainfall claims, noting a decline in rainfall over 99 years of analysis with a p-value (0.832) more significant than α (0.05).

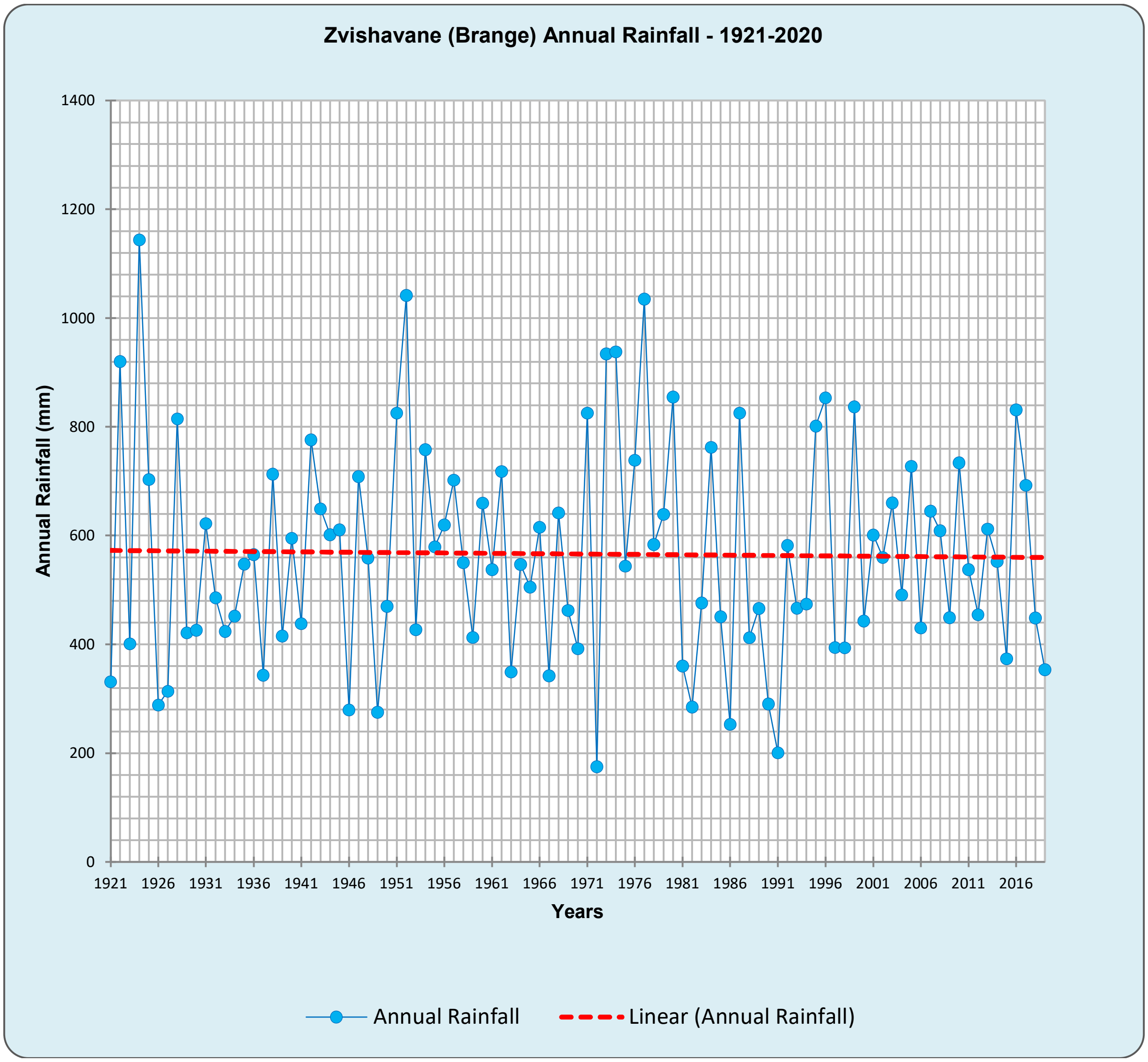

Figure 4.20 Zvishavane (Brange) Annual Rainfall Trend.
Source*: Author, 2021*

Although the study results concluded that there is an insignificant statistical decline in rainfall for both districts, the mean rainfall for Zvishavane (566.29mm) is slightly less than that of Chiredzi (567.19mm). The standard deviation for the Chiredzi district (209.80mm) was higher than that of Zvishavane (197.47mm).

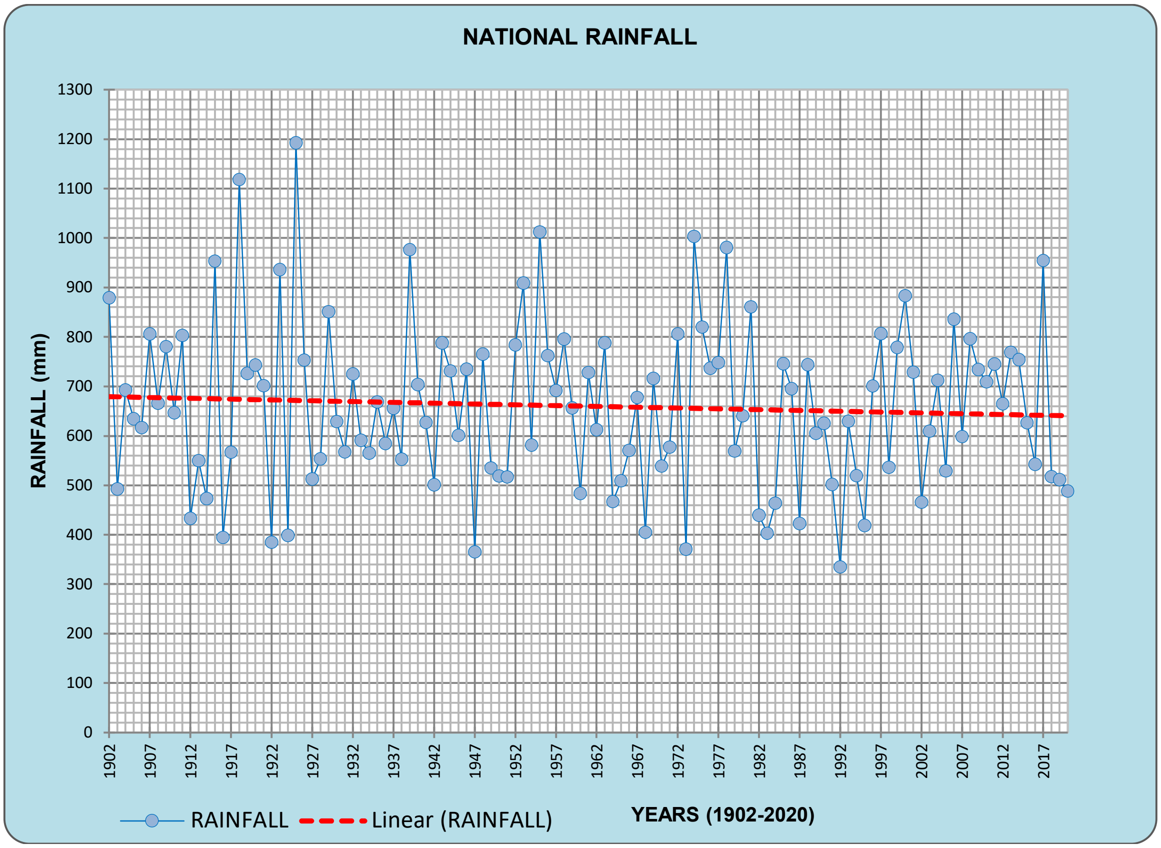

Figure 4.21 National Rainfall Trend.
***Source**: Author, 2021*

The results for national rainfall analyzed for 119 years indicated that the p-value (0.696) is more significant than the α (0.05), which revealed no trend in the series. The national decline in rainfall over the period was not statistically significant. Despite an agreement on the statistical insignificance in rainfall decline for Chiredzi district, Zvishavane district and the national level, the general trend concurred with the smallholder farmers' perceptions that rainfall was declining at a marginal scale.

iii. INCREASE IN DROUGHT EVENTS

The study noted the occurrence and increase in drought scenarios in Zvishavane and Chiredzi communities. All questionnaire, FGDs, and KII respondents noted that drought was a constraint that resulted in water challenges, food insecurity and an increase in crop pests and animal diseases. Assessment by this study indicated that smallholder farmers experienced a decline in ground and surface water sources (Figure 4.22). Most participants believed that the reduction in water levels in different sources was due to reduced recharge and overuse by communities in dry areas. When participants were asked about their views and experiences concerning climate change-related water challenges, both male and female smallholder farmers from Chiredzi and Zvishavane districts indicated that their water sources vulnerability to climate change induced droughts that increased the aridity conditions.

Most smallholder farmers who responded in the FGD and stakeholders in KII mentioned the occurrence of droughts over the past four decades as an escalating challenge. Results revealed that some droughts remained in smallholder farmers' memories since they caused significant crises. Collectively, the communities in Zvishavane and Chiredzi indicated that drought years, including 1983, 1992, 1997, 2002, 2004/05, 2008, 2012, 2016, and 2019 had negative consequences on cleaning, domestic and irrigation water availability and access due to the drying up of boreholes and other water sources. One participant in the focus group discussion commented: "*In the early 1980s' we used to get water all year round from our 5 metres deep hand dug wells. Now, to get water, we need to deepen the wells to 20 metres or drill boreholes. The surface is dry, and the water table is getting lower and lower.*" (ZCWM05, December 2020)

Communities in Chiredzi indicated increased human-wildlife conflicts and livestock predation at water points since they are adjacent and closer to major game resources, including Gonarezhou, Save Valley Conservancy and Malilangwe. One FGD participant, who was an extension officer was quoted saying: "*The cases of livestock predation and crop raiding by game animals are increasing yearly. Wild animals break into communal areas in search of forage and water, cause damage, and spread diseases to our livestock. These losses end up causing conflicts. Climate change-induced droughts are driving wild animals' migratory patterns and behaviour.*" (CCWM07, November 2020)

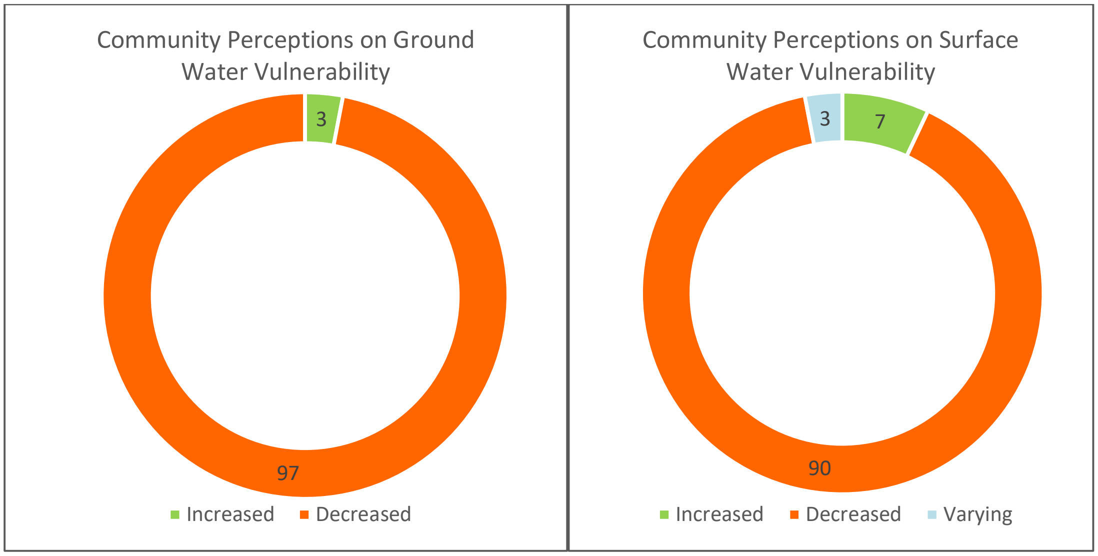

Figure 4.22 Community perceptions on groundwater and surface water vulnerability
Source: *Author, 2021*

Food insecurity was noted to be a rising phenomenon in the two districts, where smallholder farmers depended largely on rainfed livelihoods, including crop cultivation and animal rearing. Crop pests and animal diseases were key escalating challenges (Figure 4.23). Key informant interviews established that Fall Army Worm (*Spodoptera frugiperda*) was first identified in Zvishavane and Chiredzi districts in 2016 due to increased temperatures and low rainfall. Fall Army Worm continued to threaten food and fodder security. Droughts and pests' aggravating effects resulted in smallholder farmers depending on food aid from the government drought mitigation programme or World Food Programme's Lean Season Assistance Programme. Food aid with the most extensive coverage was noted to be on the increase, and the programme has been rolled out twice every three years. Livestock feeding programmes were also introduced to ensure the protection of the district's herd after the experience of 1992, 1997, 2008, 2012, 2016, and 2019 droughts impacts.

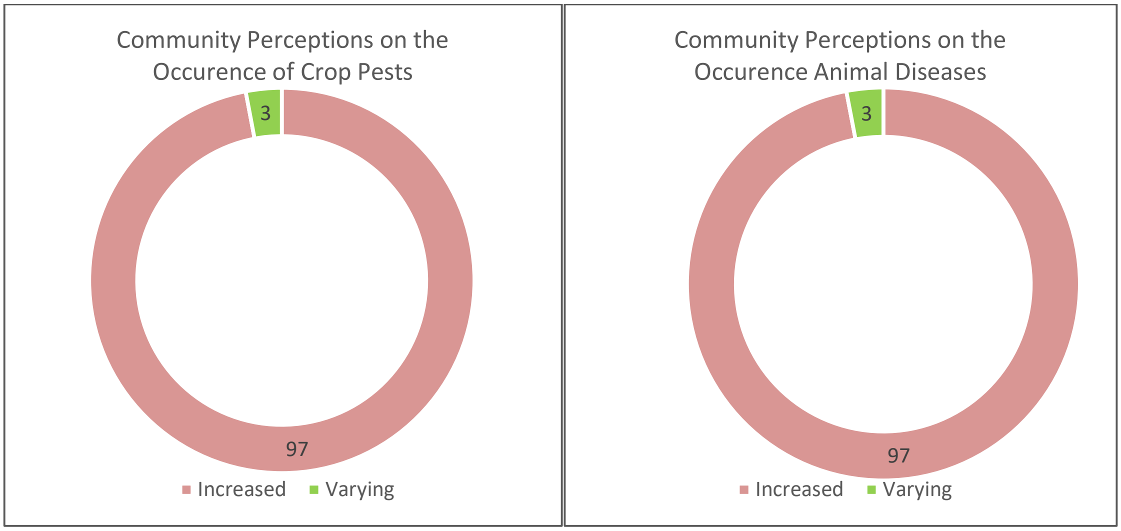

Figure 4.23 Community perceptions of the occurrence of crop pests and animal diseases
***Source**: Author, 2021*

A response to the smallholder farmer's questionnaire revealed that pests were destructive and posed food security challenges and was quoted: "*The combination between Fall Army Worm and crickets has resulted in the loss of half of my plot that was planted maize using Pfumvudza, a conservation agriculture practice.*" (ZHR119, February 2021)

Zvishavane and Chiredzi districts recorded alarming livestock deaths from various diseases (Tables 4.5 and 4.6). Some of the diseases and deaths were aggravated by the increase in temperature and shortage of clean water for livestock drinking.

Table 4.5 Animal diseases in the Zvishavane district

Name of Diseases	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Lumpy skin disease	834	0	0	0	0	294
Ephemeral fever	168	234	78	0	0	126
Blackleg	468	378	141	86	23	0
Botilism	34	42	11	14	18	7
Heartwater	47	28	32	12	18	9
Anaplasmosis	16	14	13	11	0	0
Footrot	6	3	4	0	0	0
Sub Total	**1573**	**699**	**279**	**123**	**59**	**436**

***Source**: Author, 2020*

One farmer in the Rupangwana area of the Chiredzi district was quoted saying: "*In 2020, between August and September only, I lost 35 out of 36 cattle due to droughts and diseases. I am left with one calf. This was our saving, source of income and wealth that the family accumulated over the years.*" (CHR183, September 2020)

Table 4.6 Animal diseases in the Chiredzi district

Name of Diseases	2016	2017	2018	2019	2020	2021
Heartwater	3271	2816	4933	4761	1223	956
Theileriosis	5295	4731	3922	4396	2063	908
Lumpy skin	101	118	215	3019	3175	3721
Blackleg	501	377	286	397	404	502
Bovine Ophthalmia	104	193	87	156	302	119
Sub Total	**9272**	**8235**	**9443**	**12729**	**7167**	**6206**

Source*: Author, 2020*

Due to climate change, livestock in dry areas is affected by temperature increase, water scarcity and shortage of pastures that affect animal health and nutrition. One farmer in the Ndali area of Chiredzi counted the loss from the intensified impacts of temperature rise and was quoted saying: *"Since 1992, we have experienced a drought that killed donkeys and goats. We know from history that these animals have been tolerant to harsh conditions, including drought. This time, many donkeys and goats have succumbed to 2012, 2016 and 2019 droughts."* (CHR230, October 2020)

4.2.3 CLIMATE CHANGE-RELATED OPPORTUNITIES FOR SMALLHOLDER WATER MANAGEMENT

Despite the constraints presented by the study in section 4.1.2, the respondents cited several climate change related opportunities in smallholder water resources management. The research findings indicated that water harvesting, increase in development funding, livelihood diversification, increased investment in irrigation development, technological transfer, climate-compatible policy formulation, and knowledge transfer were key opportunities from which smallholder farmers in dry areas can derive benefits.

4.2.3.1 WATER HARVESTING

Results from the study revealed the existence of a basket of water harvesting techniques used and known by smallholder farmers in the Chiredzi and Zvishavane districts. The respondents indicated that surface water, groundwater and rainwater harvesting were commonly practised in different locations within the study area and are being adapted to the changing climate and water demands.

i. Surface water harvesting

The study noted that surface water harvesting practices were in the form of wetlands water sources, day and night storage dams, and weirs. During the data collection, field observations at Rupangwana irrigation in ward 4 noted the construction of a night storage dam which abstracted water from Save River for irrigation purposes. The construction of the earth dam was implemented together with the irrigation expansion under the IFAD-funded Smallholder Irrigation Revitalization Programme (SIRP). Results further highlighted that smallholder farmers in the Ndali and Chingoji areas of Chiredzi and the Marirangwe area in Zvishavane (Section 4.3.4 and Figure 4:28) used protected springs and wetlands, respectively, to support 331 households with domestic, irrigation and livestock water throughout the year.

A total of 20 small-scale households and institutional rainwater harvesting facilities were identified in Chiredzi and Zvishavane districts. The most practised rainwater harvesting technique was the rooftop method, also known as roof catchment. This technique was only used by households with housing structures roofed with asbestos, tiles, and zinc, leaving out most smallholder farmers with a thatched roof. Through focus group discussion, the water point committee member commented that: *"Most households harvest plenty of clean water directly from the sky during the rainy season. That time, the number of households that queue for water at borehole, wells and springs becomes less since roof catchment rainwater harvesting reduces conflicts at water points as well as walking distances by women."* (CCWM188, September 2020)

Results of the FGDs indicated that rainwater was a short-term but high impact opportunity. Smallholder farmers reported that they store rainwater harvesting in plastic containers, 20 litres buckets and 50 litres dishes, and those with access to drums have the advantage in storing more water at the household level. Key informant interviews reported that institutions like schools

store water in plastic and concrete tanks. Most smallholder farmer participants of the FGD felt they needed to address rainwater storage capacities. One individual stated that:
"Despite the poor distribution of rainfall that we have been experiencing, in most cases, we receive heavy rainfall such that one rainfall event can yield more water that can be stored and used for the whole year if we have bigger storage. We only store a few drums and 20 litres buckets of water for use during the rainy season because we do not have huge storage facilities required to keep our water safe for the year." (ZHR74, December 2020)

Based on the lived experiences and practices, the study further pointed out that water storage facility was a challenge that needed redressing to increase the impact of rainwater harvesting opportunities. These results agreed with FAO (2021); Government of Zimbabwe (2012); IFAD (2016) and Niang et al. (2014) findings that Zimbabwe and other African countries' annual renewable water resources (ARWR) are lower than those of other developing countries in the region, partly due to infrastructural underdevelopment.

ii. Groundwater harvesting

The study identified groundwater development as a great opportunity driven by the need to counter climate change impacts. The four main groundwater harvesting sources that emerged from the discussion were deep wells, shallow wells, springs, and drilled boreholes, that the study identified as important sources of water to most smallholder farmers. Most of the respondents to the household questionnaire indicated that harvesting groundwater was beneficial to smallholder farmers in arid areas who used the water for domestic, livestock and irrigation purposes. The findings of this study further indicated that groundwater was a great opportunity for the Chiredzi district, where most of its sources were identified to be perennial, with 81 percent of the borehole, 77 percent of deep wells, 70 percent of shallow wells providing water to communities throughout the year, as indicated on Figure 4.9. An analysis of field observation and direct measurements data for the Ndali community in ward 5 of the Chiredzi district indicated the existence of a deep-seated and high-yielding aquifer (Figure 4.10), with a borehole yield recorded after a 12-hour capacity test using two-horsepower pump exceeding 10,600 litres per hour. This supported the perenniality of the boreholes in the Chiredzi district, further pointing out the greater potential for groundwater development.

It emerged from the key informant interviews, field observations and direct measurements that the potential of groundwater harvesting was dependent on the hydrogeological formation of the borehole site and the technical capability of personnel involved in the hydrogeological surveys. Whilst the Ndali borehole in Chiredzi indicated the existence of a deep-seated and high-yielding aquifer, the findings from field measurements, observations and FGDs indicated that Timba borehole in the Murowa area of Zvishavane was one case of a seasonal borehole that was reported to have run dry during peak-dry season (usually September to November). The measurement results for post drilled site hydrogeological survey indicated a hydrogeological formation of the Timba borehole (Figure 4.24).

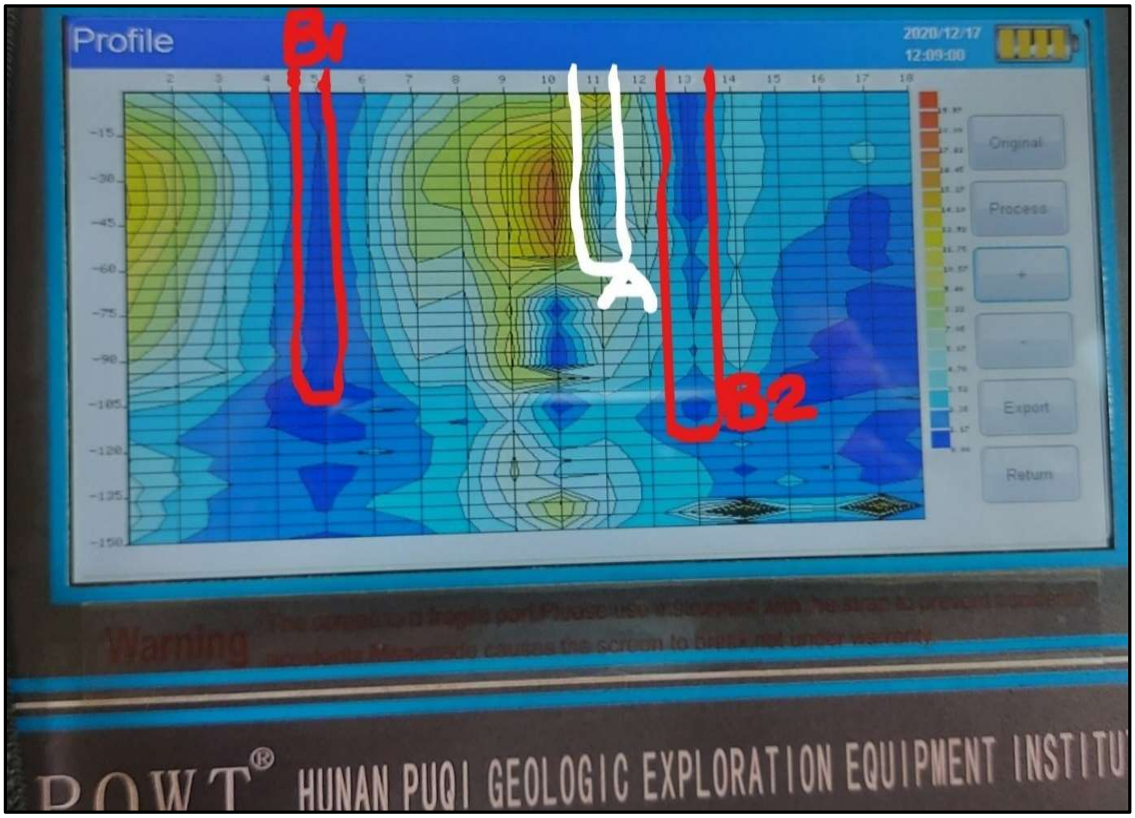

Figure 4.24 Unprocessed groundwater profile for Timba
***Source**: Author, December 2020*

In the case of the Timba Borehole in the Murowa area of Zvishavane, a 60 metres deep borehole was developed at a point marked A in Figure 4.24. Results further revealed that the borehole was drilled at a point with impervious rock that indicated shallow weathering and a small area with groundwater storage, as indicated by the blue colour that depicts the most suitable points for borehole drilling. From the analysis, the yellow and orange-red indicated a section with low chances of groundwater occurrences. Furthermore, results indicated that the most productive area with high chances of groundwater, marked B1, was missed by 6 meters and the second greatest potential site B2 was missed by 2 metres from the drilled point (Figure 4.24). The Timba site analysis revealed that groundwater in the Zvishavane district occurred at higher depths, as indicated by the blue zones that depicted aquifers in depths ranging from 90 to 150 metres. Contrary to the findings on groundwater occurrence, the Timba borehole was drilled to a maximum of 60 metres. During a focus group discussion with a water point, one elderly member mentioned that: *"What we have seen from your machine is true. When this borehole was drilled in the 1980s, the drillers from DDF spent three days drilling, hitting the rock that shook our houses. They only got the first water break after 40 metres, and they stopped at 60 metres."* (ZCWM8, December 2020)

The measurements at the Timba borehole were conducted in the presence of the DDF's water technician, who also concurred with the measurements results and commented: "*Most successful boreholes in Zvishavane district have depths of 80 metres and above. This area is arid, and most boreholes are seasonal and drilling deeper increases the chances of getting water*." (ZCWM11, December 2020)

Results of the study indicated the existence of water conflicts within the communities, which were identified to increase during the peak dry season when most surface water points and wells dry up. Water conflict at the borehole sources was also identified at the Timba borehole, where the community queued for water, waiting for the borehole to recharge. The key informant from Runde Rural District Council revealed that during the dry season, it was their routine exercise to solve conflicts at water points due to increased water demand and reduced yields for most seasonal boreholes. Overall, these findings provide important insights about water harvesting in dry areas as one of the viable options for achieving water security in the face of the changing climate.

4.2.3.2 INCREASE IN FUNDING OPPORTUNITIES AND DEVELOPMENT SUPPORT BY DONORS

Water development and humanitarian-related funding opportunities were identified to be on the increase by donors, the government and development partners who give more support to water projects that address climate change issues. The results indicated that in most cases, the funding comes as a full basket that addresses more interventions, including food aid assistance for vulnerable households, agriculture production, resilience building, livestock health and nutrition, and water development. A key informant interview with one district coordinator of a local non-governmental organization (NGO) identified the influx of donor support as an opportunity and said: *"Most donors support community projects, including borehole drilling and installation when there is an emergency. During the 2019/2020 drought, the UN Appeal for external support that targeted to assist over 5.5 million rural and 2.2 million urban hungry population had a budget of USD331 million for food aid and water development."* (ZCBO2, November 2020)

Results also revealed that the increase in remittance by the diaspora community was more popular for women smallholder farmers who got support from relatives and family members in diaspora and urban areas. One smallholder woman from Chiredzi's Muteyo area commented: *"Every drought year, we depend on remittance from our diaspora family members to buy food. Most households who developed their boreholes and wells within their plots and those who built nice modern houses and installed solar systems have members in the diaspora who sent money to implement all these developments."* (CHR44, September 2020)

4.2.3.3 TECHNOLOGICAL TRANSFER FOR WATER DEVELOPMENT

The transfer of technology for water development was identified as one great opportunity with potential for increasing community water access. The use of solar-powered water pumping technology was on the increase as authorities, the private sector, donors, and beneficiary communities were increasingly becoming more climate sensitive. Results of the key informant interviews with two District Water Technicians from Chiredzi and Zvishavane pointed out the increased adoption of clean solar water pumping technologies by communities. One key informant from the Chiredzi district commented that: *"Solar water pumps are now cheaper and affordable. We used to have solar pump supply companies in Harare capital city only, but now they have spread to many districts, including Chiredzi. Almost all boreholes being drilled over the past 3 to 4 years have been installed with solar water pumps, except for the low-yielding boreholes that we recommend installing a hand pump that takes time to drain the few waters from the low-yielding aquifers."* (CLEP3, October 2020)

The key informant from Zvishavane further buttressed the finding that technological transfer was increasing, supporting communities to cope with climate change impacts on water. The increased the influx of equipment and machinery was confirmed by the key informant who commented saying: *"Borehole drilling used to be a sole business for DDF and a few commercial private companies. The influx of cheap drilling companies from India and South Africa made equipment was a relief that led to the reduction in the cost of drilling boreholes. A 40-metre-deep borehole used to cost around USD6,000.00 in 2007, and the current average drilling cost of the same depth is USD1,200.00 per borehole."* (ZLEP7, October 2020)

Overall, the results indicated that improvements in technological transfer due to climate-related developments have proved to be key opportunities that communities and nations need to leverage and strengthen their mitigation and adaptation plans.

4.2.3.4 POLICY AND PROGRAMME FORMULATION

From various KIIs, FGDs, and secondary information reviewed, the results of this study revealed that various efforts were made at the national, sub-national and local levels in order to influence the development of new policies, new programs as well as aligning old policies and programmes with climate change. Whilst national Rural District Council indicated that these policies and programmes are implemented within their jurisdiction, making their communities the first to benefit from such interventions. A district government informant who has been involved in the implementation of climate change-related projects, including "Coping with drought and climate change" and the "Enhancing Community Resilience and Sustainability", both projects funded by UNDP and implemented in the Chiredzi district indicated that the interventions produced tangible community benefits, lessons important for future program and policy development. The key informants further indicated that it was an excellent opportunity for communities in dry lands that climate change has resulted in the realignment and new development of climate adaptation policies and programmes that support local communities. -level policies like the National Climate Policy and Zimbabwe Wetlands Policies were developed by the government, the key informants from Zvishavane's Runde Rural District Council and Chiredzi

4.2.3.5 KNOWLEDGE TRANSFER OPPORTUNITIES

Results from the research indicated that Indigenous Knowledge Systems (IKS) and practices, modern scientific knowledge, research, and innovative products are essential knowledge products that can be developed and transferred for the benefit of smallholder farmers in arid areas struggling with climate change. The KII and FGD participants highlighted that climate change might result in opportunities that communities may derive benefits from the changes and develop their social, economic, and physical well-being. In the order of priority, the following were identified as key benefits that smallholder farming communities may derive from climate change:

i. Extension services were improved by sharing best practices and information through different platforms, including digital technology.
ii. Climate information required for planning will be shared through multi-stakeholder and multi-sectoral platforms.
iii. Capacity-building training will enhance skills transfer across individuals, institutions, communities, countries, and the world in support of climate change programs.
iv. Policies and practices were formulated and aligned with the changing climate, supporting resilience and adaptation of communities at-risk.
v. Research support will increase as government and academics try to solve challenges including rising temperatures, weather extremes, and harsh climatic events.
vi. New hybrids and varieties in crops and livestock will be developed to improve farmers' resilience.
vii. Best practices, including climate-smart agriculture, will be introduced and scaled up in marginal rainfall areas to ensure climate mitigation and adaptation.
viii. Increased precipitation was noted in some years as a blessing to the community during cyclonic events and has improved crop production and replenished water sources in arid areas.
ix. Conservation practices were scaled up, incorporating new information about the changing climate.
x. Knowledge gained played an influential role in behaviour change for resource users and businesses, increasing business.

4.3 LOCAL INSTITUTIONS AND CLIMATE-COMPATIBLE SMALLHOLDER WATER MANAGEMENT

The study considered institutional arrangements since institutions were identified as important elements in climate-compatible water resources management and development. Given the challenges encountered by smallholder farmers in managing water resources in dry areas, it was important for this research to establish existing institutions, their mandate, capacities, and institutional gaps in supporting climate-compatible water resources management. This section presented results in line with the study's second objective on local institutions' roles and capacity in enhancing climate-compatible smallholder water.

Results from the study indicated the existence of local institutions, which are Rural District Council (RDC), Traditional Leaders, Government Departments, Local Elected Political Leadership, Village Health Workers, Farmer Cooperatives, Ward Development Committees (WADCOs), Village Development Committees (VIDCOs), Disaster Risk Reduction (DRR) Committees, Asset Management Committees (AMCs), and Village Pump Minders (VPM). The study's findings further revealed that the identified institutions had their mandates, delivery mechanisms and challenges in fulfilling these mandates. Absence of certain institutions to fill the identified institutional gaps and the unmet needs of smallholder farmers in dry areas was noted.

4.3.1 INSTITUTIONAL ROLES AND CAPACITY IN CLIMATE-COMPATIBLE WATER MANAGEMENT

This section presented research findings on existing institutional roles and capacity in addressing climate change and water resources management in dry areas. Major research findings indicated that most institutions played service delivery, regulatory, governance, policy and representation roles, as detailed in the following section.

i. RURAL DISTRICT COUNCILS (RDCS)

The study identified the existence of four local authorities in the Chiredzi and Zvishavane districts: two being rural district councils (RDC) and two being urban councils. When asked about their founding history and background, key informants from the Chiredzi RDC and Zvishavane’s Runde RDC indicated that RDCs were local authorities covering rural communities. They were constituted by the Act of Parliament, the Rural District Council Act, Chapter 29:13. This, therefore, made the RDC a constitutional body that the central government gave a specific mandate through the RDC Act.

Key informant interviews and review of secondary information revealed that Chiredzi Rural District Council has a total of 32 rural wards, whilst Runde Rural District Council has 19 wards under their jurisdiction. When asked about their mandates, results from key informant interviews with officials from the two RDCs revealed that the councils were responsible for service delivery and promoting development activities targeting the rural population. One of the officials commented that: *"As the local authority, our council provides social services, infrastructure development and information dissemination through our structures and network to community members in our jurisdiction areas."* (CLAR1, September 2020)

The local authorities' administrative and technical services roles were identified as key enablers to fulfilling the RDCs' mandate. Another key informant interviewee from the one RDC alluded to the notion that their service delivery basket was inclusive of climate and water issues and therefore commented: *"Our council has an Agriculture and Environment department responsible for climate change and water resources management, among other functions and services."*(ZLAR2, December 2020)

When asked about the partnerships that Council promoted in the areas to do with climate change and water resources management, an official from one Council commented that: "*As the custodian of community development, our Rural District Council is responsible for creating development space for all development actors through issuance or permits and operational agreements that regulate different actors' operations*." (CLAR9, October 2020)

While most (92%) community members with positions in the ward and those holding extension and other leadership roles were clear about the functions of RDCs, it was a different story for ordinary communal farmers. Most farmers remembered the specific roles of RDCs, including periodic road maintenance, collection of annual taxes, issuance of traders' permits, and regulating buildings for shops at rural service centres. One woman from the Mtambi area of Zvishavane commented that: *"Our Council is responsible for road maintenance, collecting levies from every household and shop licensing. If there are other roles that they do, I have not yet seen them here, maybe if they are doing in other wards."* (ZCWM20, January 2021)

Interestingly, the study noted different views from the served communities about the roles that RDCs play in service delivery. A smallholder woman farmer from the Rupangwana area in the Chiredzi district commented that: *"We have several boreholes drilled by council budget in this ward. It seems that the Council is more serious about developing water in our district because we heard that the Council bought new borehole drilling equipment to service the community."* (CHR255, September 2020)

Results from the key informant interviews and review of secondary data revealed that while Chiredzi RDC had a by-law, Runde RDC does not have any by-law to support its development and plans. Coordination mechanisms for the humanitarian, private sector and development interventions were managed by the RDC institution in Chiredzi and Zvishavane.

ii. LOCAL ELECTED POLITICAL LEADERSHIP

The study revealed that local elected political leadership are essential institutions involved in key decision-making around the research topic. Elected Councillor and Member of Parliament were identified as holders of influential offices in Zimbabwe's RDCs and national assembly. Results from key informant interviews with eight (8) councillors and one Member of the Parliament from the two districts indicated that political leaders held several offices at national, sub-national and local levels. The study results further indicated that Chiredzi Rural district has 32 ward councillors and 4 Members of the Parliament, whilst Zvishavane's Runde Rural District has 19 ward Councillors and 2 Members of the Parliament (Table 4.7).

Table 4.7 Local Elected Political Leadership

Rural District	Ward Councillors	Members of Parliament
Chiredzi	32	4
Zvishavane/Runde	19	2
Total	**51**	**6**

Source*: Author, 2021*

Key functions for Councillors include controlling the decision-making processes at RDC as necessitated by their influence at different portfolios in RDC sub-committees and full councils that make final resolutions about partnership engagements, resources allocation and negotiations with investors and developers. The finding indicated the functional sub-national structure within local governance in Zimbabwe. When asked about the importance of a Ward Councillor and the elected Member of Parliament, one female participant from a Zvishavane focus group discussion stated that: *"Political representatives are the conduits for information and development linking the national, provincial, district and ward levels depending on their levels of representation."* (ZHR36, January 2020)

Another commented that: *"Information dissemination involving droughts, floods, COVID-19 and other diseases outbreak is sent from the Council and District Development Coordinator to all Councillors who then inform their representative communities."* (ZHR53, January 2021)

The comments from community views about the roles played by the elected political leadership indicated that elected political leadership institutions play important role in climate information dissemination and development of their community. Whilst Ward Councillors are located at the lower tier, and Members of the Parliament are at the upper and middle tier (national and sub-national level) within the system of devolution of power, the results from this study indicated that the Local Elected Political Leadership institution is created by democratic voting or sometimes by appointment process. The study further indicated that the qualification of the elected Member for them to deal with climate change and other developments was not considered, as indicated by the lead farmer of Muteyo garden, who commented: *"We do not consider the candidate's qualifications for one to be voted to be a Councillor or to be our Member of Parliament. The candidate needs to convince more people in different ways to win the election process."* (CHR370, November 2020)

Whilst the Local Elected Political Leadership was identified as a key institution, the research findings further pointed to the need for their capacity building with training packages to ensure that the institution fully understands and solves critical development needs for their electorate.

iii. TRADITIONAL LEADERSHIP

The study revealed the existence, membership, and functions of traditional leadership institutions in Zimbabwe. Chiefs, headmen and village heads were identified hierarchically as members of the traditional leadership institution. Key informant interviews within the government's Ministry of Local Government and Public Works at the district level revealed that the traditional leadership was one of the oldest and longest-lived institutions that existed and were continuously shaped by events from the pre-colonial era, colonial, and post-independence era. The key informants indicated that the current institution is constituted and shaped by existing legal frameworks, including the Traditional Leaders Act (Chapter 29:19), which provides an appointment framework and the Rural District Councils Act (Chapter 29:13), which offers roles and responsibilities of traditional leaders over their assigned areas of the jurisdiction.

When asked about their roles in climate-compatible smallholder water resources management, both the key informants from the Ministry of Local Government and Public Works and the representatives of the Traditional Leadership institution indicated that the governance of communal lands and their resource function was one of their broad mandates. Traditional leaders in Zvishavane indicated that protecting wetlands and springs using indigenous knowledge systems has been one of their duties that has safeguarded water resources in dry communities.

When asked about their institutional role in climate change, the headmen and village heads indicated that they had been the centre regarding seasonal climate forecast and information dissemination. One of the village heads in Zvishavane was quoted saying: "*We use our traditional and local knowledge to guide community practices on areas around conservation of natural resources and foretelling the future rainfall trends. Traditional leaders observe different animals, plants and weather patterns, and lead in traditional ceremonies to ensure that the seasonal climate forecast is free from climate hazards like lightning, harsh winds and storms*." (ZLCL2, February 2021)

The planning roles were also identified clearly from the key informant interviews with the Headman in Zvishavane, who responded that: *"As traditional leaders, we are responsible for convening community meetings about climate change and water development and resources governance activities."* (ZLCL3, February 2021)

When probed about conflict resolution roles during a key informant interview, one traditional leader in the Chiredzi district indicated that it is their institutional responsibility to provide mediation in cases of conflicts, as commented: *"Mediation and solving conflicts whenever they arise and are reported is one key function of the Village Head, Headman or Chief. Recently, there were conflicts in Tahani village about water use, and we have resolved them through mediated dialogue."* (CLCL7, September 2020)

As an anticipatory and adaptive approach to climate change by the traditional leadership institution, officials from the AGRITEX extension services department in the Zvishavane district indicated that the traditional leadership institution maintained a unique programme that was developed and sustained over time to mitigate the impacts of disasters. The extension officer commented that: *"The popular agricultural programme known as Zunde raMambo is being implemented by our Chiefs with support from the government. Chiefs traditionally produced and stored grain and other food reserves distributed to needy households during the droughts."* (ZLEP1, September 2020)

The extracts from the key informant interviews indicated that traditional leadership institutions have been functioning as regulatory, service provision, social safety net, and coordination arms of the society. These roles were important in shaping how communities in rainfall marginal areas responded to climate change and water management. Local context-specific and traditional applicable practices in climate information services and water resources management were therefore sustained by legal frameworks and indigenous knowledge systems shaped by the traditional leadership institution.

iv. GOVERNMENT DEPARTMENTS

Different government departments were identified as existing and offering various support mechanisms to rainfall marginal communities concerning climate change and smallholder farmers' water management. The majority of the questionnaire respondents and key informants pointed out the existence of key departments and offices, including the Agricultural Extension and Technical Services (AGRITEX) department, District Development Fund (DDF), Meteorological Services Department, Department of Livestock and Veterinary Services (DLVS), Environmental Health Technician (EHT) under Ministry of Health and Child Care (MOHCC), Water Bailiff under ZINWA, Department of Agricultural Engineering Mechanization and Soil Conservation, Ward Coordinators of the Ministry of Women Affairs Community Small and Medium Enterprises, Zimbabwe Electricity Supply Authority (ZESA), Department of Social Development (DSD) and the Grain Marketing Board (GMB).

The KIIs with representatives of government departments in Chiredzi and Zvishavane districts provided vital information to the study about their institutional mandates and capacities concerning the study, as presented in Table 4.8.

Table 4.8 Government institutions' mandates and capacities

Government Institution	Roles and Mandates related to Climate Compatible Water Resources Management	Findings related to Institutional Capacity
AGRITEX	Offer public technical extension services, awareness, education, and farmer advisory. Training soil and water conservation as well as weather and climate information dissemination.	Discharged their duties and indicated limitations with funding for outreach. The advantage and momentum were on the representation at the local level in every ward. The institution indicated the need for refresher training and equipment to cope with the new normal brought about by climate change.
DDF	Responsible for conservation work programmes and infrastructure development, including roads, water storage and boreholes. Responsible for policy regulations on water resources development and management at the district level	They have implemented some activities, although the technology transfer mandate was a challenge due to funding limitations. DDF was a recipient of government, donor, and private sector sourced technology and equipment. Skills gaps and funding for operation and maintenance, standardizing and sustainability for technologies.
Agricultural Engineering, Mechanization and Soil Conservation	Responsible for soil and water conservation, value addition and technical design of farm infrastructure	Identified as the driving force for Good Agricultural Practices and construction work for large night storage water reservoirs at Rupangwana and Dendere irrigations. They are spread thinly across the district, and no local extension officers despite the need.
Meteorological Services Department (MSD)	Responsible for the collection, analysis and dissemination of scientific weather and climate-related information services.	MSD is thinly spread and needs strategies for improved coverage in data collection and information dissemination. Only one office per district and situated in urban areas. Do not have a network of centres to

		cover the geographically spaced smallholder communities in the targeted districts.
Veterinary Services Department	The official regulator of animal health.	Managing and coping with new animal diseases is a key challenge. Key activities implemented in Chiredzi and Zvishavane include cattle dipping and control of livestock diseases. Implementation of water management at dip tank working hand in hand with Dip Tank Committees.
Ward Coordinators from Women Affairs department	Facilitate planning and implementation of Income Generation Activities (IGAs), monitoring and technical support for registered cooperatives.	Key activities at the community level depend on funding. Monitoring village savings and lending has been key in resilience building for at-risk communities. The ward coordinators are thinly spread and indicated that they could not offer capacity building to all savings groups and cooperatives every time.
Environmental Health Technician (EHT) from MOHCC	Responsible for protection services for water points, water points monitoring and a member of the DRR committee	Responsible for the technical and regulatory support around the development of water, sanitation, and hygiene infrastructure at the community level in line with Ministry of Health and Child Care activities. Work with village health workers and the water point committee to manage and monitor water points.
Water Bailiff from ZINWA	Working under ZINWA, monitoring and managing dams and rivers' water storage and discharge information from major reservoirs. Aid in	The Bailiff is not stationed in all communities. At large-scale projects, they provided raw water allocation and rationing for irrigators depending on controlled dams.

	decision making, policy compliance and regulation in raw water use.	Monitoring the use of water permits by irrigators and preventing illegal abstraction. A gap exists in groundwater monitoring for community and individually owned boreholes to track the depletion and performance of groundwater.
Department of Social Development (DSD)	Coordinating District Drought Relief and other aid programmes. Regulator of Non-Governmental Organizations (NGOs) using PVO Act Ch. 17.05.	Provide social protection for vulnerable and operational framework for NGOs providing aid to communities. The department is centralized at the district level and works with voluntary structures and through other departments in service delivery.
ZESA	Energy provision for smallholder water pumping and irrigation systems.	With economic challenges, electricity supply was reported as erratic, with costs unbearable for communities to access the infrastructure required to connect. ZESA enjoyed the monopoly, and the institutional arrangement requires diversified players with options for renewable energy affordable to all smallholder farmers.

***Source**: Author, 2021*

v. VILLAGE HEALTH WORKERS (VHW)

A community-based Primary Health Care (PHC) voluntary institution in the form of the Village Health Worker model was identified through smallholder farmers' household questionnaires, KIIs and FGDs. The KIIs with one of the Environmental Health Technicians indicated that Village Health Workers are community-based voluntary men and women enrolled by the Ministry of Health and Child Care on the Village Health Worker scheme. When asked about their roles, one Village Health Worker who participated in an FGD in Chiredzi indicated that their roles were awareness raising on vaccinations, diseases outbreak surveillance, data collection for the Ministry of Health and Child Care, and community health and hygiene promotion facilitation. When asked about village health workers' role in climate change and water resources management, one smallholder farmer indicated that the current functions are more inclined to water and sanitation service delivery. The respondent stated that: *"Village Health Worker promote access by local communities to adequate sanitation and clean water by distributing water purification tablets."* (CHR300, October 2020)

Other responses to the question indicated that VHWs provide comprehensive monitoring of hygiene practices at waterpoints and help with enforcement mechanism for water source protection. This was noted by a Water Point Committee (WPC) representative who commented saying: *"As part of their supportive role to our water point committee, the Village Health Workers provide guidelines, practices and monitoring on cleaning and protection of wells and boreholes to prevent water source contamination."* (CCWM11, November 2020)

vi. FARMER GROUP-LED COOPERATIVES

Different farmer group-led cooperatives were identified as key institutions in almost every ward and in different forms. The study results indicated that farmer group cooperatives were formed under various modalities and regulated differently over time. The study identified farmer group-led cooperatives involved in community gardens, irrigation, savings clubs, beekeeping, poultry, and goat rearing through key informant interviews. Some of the groups participated in the focus group discussions that sought to generate understanding about their formation, roles and responsibilities and their impact on supporting climate-compatible smallholder water resources management.

Farmer group-led cooperatives existed in different forms depending on the community context. Their purposes were varied, and some of their roles identified by the study were:

a) Crop and livestock producer groups that have history and experience in the practical implementation of programmes and strategies around climate change.
b) Lead farmers were identified as key players in knowledge transfers through different training activities, including exchange visits, field demonstrations, and farmer field schools.
c) Conducted trials and provided research sites for most climate-compatible water resources management practices.

Key constraints that has been affecting farmer group led cooperative include:

a) Lack of sustainable funding modalities required for scaling up best practices.
b) The absence of farmer organizations at every level meant that planning at the community level was affected by gaps and a lack of representation from one community to the other.
c) Limited information on climate and water resources hindered most communities from climate-compatible water resource management planning.

vii. VILLAGE DEVELOPMENT COMMITTEE (VIDCO) & WARD DEVELOPMENT COMMITTEE (WADCO)

In their account of the existence of local institutions, respondents of the key informant interviews from both Runde RDC (Zvishavane) and Chiredzi RDC indicated that VIDCOs and WADCOs were institutionalized in every village and ward respectively, as guided by the RDC Act (Chapter 29:13). Results from KIIs and FGDs indicated that VIDCOs and WADCOs are local level administrative committees that are chaired by village heads and elected Councillors respectively. Members of the VIDCOs indicated that they are accountable to village assemblies whilst members of the WADCOs are accountable to the ward assemblies. Village assemblies and ward assemblies were identified by focus group discussions that they are chaired respectively by the Village Head and Headman within their jurisdiction in line with Traditional Leaders Act (Chapter 29:17). When asked about membership, Rural District Council's key informant Interviewees indicated that VIDCOs draw members from residents of the village above the age of majority, 18 years. On the other hand, the Mutambi ward indicated that WADCO membership was drawn from each village's village head and the village secretary, who were seconded to represent their village interests inward development committees.

Interestingly, the study results revealed a disconnection between the mandate of the WADCOs and the actual practice on the ground. One key role of land levy collection superseded all other roles, including conservation of natural resources and planning for development projects, as commented by one participant of the focus group discussion who commented saying: *"As village heads, we are mainly responsible for the collection of land levies and remit them to Council as per the directive and requirement of the law."* (ZLCL1, January 2021)

Most members were unaware of the legal framework that constituted their committees. Furthermore, key informant interviews indicated a shift from the VIDCO's and WADCO's roles. The VIDCOs mainly considered their committee's role as village administrators, indicating they were unsure about their key natural resource conservation roles.

A focus group discussion with a WADCO in Chiredzi's Chief Gudo area and Zvishavane's Mutambi area indicated that the main functions of WADCOs was mainly coordination of ward developmental plans drawn from village development committee (VIDCO) plans. Despite being the highest ward-level development planning and coordination institution, the study's results indicated that WADCOs' multi-sectoral approach addressed any development and humanitarian needs within the ward. Lack of specialization by members in climate change and water management and lack of climate information and funding were huge setbacks. In line with these setbacks, one village head commented: *"Our village plans feed into ward development plans, but the challenge remains the unavailability of the required money to implement our activities. Due to lack of funding, we still have borehole drilling activities rolled over from one plan to another for several years."* (CLCL13, November 2020)

viii. DISASTER RISK REDUCTION (DRR COMMITTEE)

The study results indicated the existence of ward-based Disaster Risk Reduction (DRR) committees in all eight targeted wards. Two (2) of the DRR committees (one from Chiredzi and one from Zvishavane) participated in the FGDs. Key informants from the Chiredzi RDC indicated that this institution was recently developed, as commented: *"DRR Committee is a new institution developed in 2018 for communities supported by a United Nations Development Programme's ZRBF project. The committee's roles are not directly confined to climate and water resources. However, they offer cross-cutting roles around mapping key hazards, raising community awareness, providing triggers for early warnings and feeding directly into WADCOs planning."* (CLAR2, November 2020)

Secondary information sources indicated that the DRR Committees were key in helping the development of Ward Development Plans in Chiredzi district and Disaster Risk Management and Adaptation Plan in Zvishavane districts. One of the participants of the FGD and a member of the DRR committee indicated that limited access to climate information was a major setback in their planning as commented: *"As a DRR committee, we are equally caught unaware and unprepared whenever there is climate change and weather-related disasters because we do not* *have access to accurate and real-time climate and weather information services."* (ZLCL2, October 2020)

ix. INDIGENOUS SEASONAL CLIMATE AND WEATHER FORECASTER

The study identified the existence of indigenous or traditional local climate forecasters in both the Chiredzi and Zvishavane districts. These are individual men and women who have mastered using indigenous knowledge systems (IKS), indicators and practices to predict short to medium-term weather and seasonal climate forecast using cultural and traditional means. When asked about their roles, the smallholder farmers who participated in FGD indicated that they were key in providing basic traditional seasonal climate and weather outlook with some levels of accuracy. One participant commented that: *"Within our communities, we have spirit mediums, diviners, community elders, and other community members with experiences in predicting weather conditions and the seasonal outlook based on their knowledge, biophysical indicators and spiritual roles."* (CHR340, November 2020)

The use of biophysical indicators (flora and fauna) to offer short-term weather forecasts and seasonal climate predictions was revealed to be the practice most forecasters utilized in their different contexts. Different tree species, including *Parinani curatelliofolia* (muhacha/muchakata) and *Strychnos megadascariensis* (mukwakwa), insects, shooting of leaves for certain trees, signalling the beginning of rain season within the shortest period. In Chiredzi, winter cloud setup was commonly linked to signal plenty of rains in the following season. Certain insects and animal behaviour, wind directions, birds, fruits and the position and status of the moon were explained by the focus group discussion participants as linked to different performance in rainfall and temperatures within the short (days) to medium (seasonal) term ranges from the forecast.

The study's results revealed that individuals involved in seasonal forecasting were considered torch bearers in cultural norms and preservations of sacred places, including springs and wetlands. This also explains the long-term existence and protection given to Chiredzi's Ndali and Chingoji springs of 1930 and 1972, respectively.

Lack of standardization, context-specific practices and lack of documentation was cited as a key challenge around evidence-based planning. However, the community believed that local climate and weather forecasters who use indigenous knowledge systems might face constraints that impact its sustainability and full adoption. One smallholder farmer commented that: *"The practice is fading slowly since the older and knowledgeable generation is dying without transferring skills to the younger ones."* (CHR359, October 2020)

x. COMMUNITY-BASED ORGANIZATIONS (CBOs) AND NON-GOVERNMENTAL ORGANIZATIONS (NGOs)

Results from the research revealed several CBOs and NGOs operating in the two districts. The CBOs and NGOs are local, national, and international organizations that are constituted and legally approved to implement development and humanitarian work by the government. Some exist as registered PVOs (under PVO Act Chapter 17:05), registered Trusts through the High Court, faith-based organizations affiliated with religious groups and those operating at the grassroots level as CBOs with the permit and approval of the local authority. Key informant interviews indicated that some CBOs and NGOs forge partnerships and develop consortia for project implementation. AGRITEX officers in Chiredzi indicated the existence of the ECRAS consortium, and in Zvishavane, the extension staff pointed out the existence of ECRIMS. Both ECRAS and ECRIMS, the community, revealed that CARE International led them in Zimbabwe, and some members included Plan, ICRISAT, LID Agency and Lutheran Development Services. Christian Care, Wildlife & Environment Zimbabwe's Lowveld Environmental Awareness Programmes (LEAP), Mwenezi Development Training Centre and ADRA were some of the organizations noted to be operating in the study area, addressing water management in the face of the changing climate.

Through KIIs with representatives of CBOs and NGOs for Chiredzi and Zvishavane districts, the study revealed that all CBOs and NGOs complemented government efforts in development activities, including water management and climate change. The key informants from RDC further indicated that CBOs and NGOs are guided by a Memorandum of Understanding (MOU) to discharge their planned support programmes fully. The findings of this study indicate that the CBOs and NGOs were active in the following areas:

a) Water sources development (new borehole drilling, rehabilitation, and repairs)
b) Provision of new technology, including solar water pumping systems,

c) Enhancing community and government capacity through training,
d) Weather and climate information dissemination,
e) Food aid for vulnerable communities during droughts
f) Provision of equipment for enhancing resilience around agriculture and water, and
g) Funding for irrigation development

The study also revealed that CBOs and NGOs sometimes face challenges in executing their duties fully. One respondent from Chiredzi-based CBO mentioned that: *"Funding limitations pause key challenges in programme implementation. Our organization only covers five villages out of more than 600 villages in the district. We will be forced to discontinue our planned operations if we do not get additional funding support from our current fundraising efforts."* (CCBO1, November 2020)

The AGRITEX officer from one of the targeted communities also noted that sustainable funding was affecting CBOs and NGOs' future and was quoted saying: *"We realized that most programmes implemented by NGOs are short-term. Some have ended before they have realized their full impact. If you ask them to continue or scale up their supported activities, they indicate that funding for continuing to support the community has ended. There is a need for a more sustainable funding mechanism for the smallholder farmers to realize climate compatible water management."* (CLEP7, November 2020)

One striking result was that CBOs' and NGOs' interventions were mostly localized and climate compatible and required implementation at a scale to realize the impact.

xi. ASSET MANAGEMENT COMMITTEES (AMC)

Asset management committees identified by the research were water management institutions decentralized in various communities. The asset management committees (AMC) in both Chiredzi and Zvishavane districts were found to exist in different forms. However, they were all democratically selected, trained and are farmer and resource user-led management committees for different infrastructures developed to improve water resources management by and for the smallholder farmers. Results of the study identified irrigation management committees (IMC), Water Point Committee (WPC), Dip Tank Committee (DTC) and Village Pump Minders (VPM) as institutions that offered asset management functions as detailed in the sections that follow.

Given the above findings, it was also important to establish the role played by different institutions that fall under the asset management committees. Asset management was noted as an element in ensuring long-term sustainability in water resources management.

a) Irrigation Management Committee (IMC)

The study identified the existence of IMC in both the Chiredzi and Zvishavane districts. The IMC is a structure selected by smallholder farmers trained by technical services providers to give leadership and representation for farmers in irrigation water management and other irrigation-related businesses. In determining the importance of IMC in climate-compatible smallholder water resources management, the study's focus group discussion with members of the IMC and key informant interviews with extension officers identified the key roles and responsibilities of the IMC. IMC's overarching role was land and water resources conservation and governance. Through KIIs and FGDs, the participants from Chiredzi and Zvishavane districts were quoted as presented in the following extracts, respectively.

A smallholder farmer from Dendere Irrigation Scheme was quoted saying: *"Throughout the year, our committee is responsible for assessing and determining our crops' water requirements and planning the irrigation programme with guidance from our AGRITEX officers."* (CCWM9, October 2020)

A member of the IMC commented: *"Our work is to make sure that all members pay their membership and user fees on time as detailed in our group constitution for our scheme to operate efficiently and receive services like irrigation systems repairs and maintenance on time."* (ZCWM1, December 2020)

Other key responsibilities for the IMC in managing water resources include conflict resolution. At Timba Garden in Zvishavane's Murowa area, the Chairperson of the committee was quoted saying: *"Every year between August and November, which is the driest period, we try to manage conflicts arising from access to water at our borehole. We outsource the service of traditional leaders, ward Councillors, RDC officials and government extension officers to help resolve the increasing conflicts due to water demand and scarcity during the dry season."* (ZCWM3, December 2020)

During the field observation of Rupangwana and Dendere irrigation schemes in Chiredzi, the study results showed that the IMC were key enablers for group governance and water resources management by irrigators. Despite being elaborate about their roles and responsibilities, the IMC indicated that they required more external funding support to enhance their operation and maintenance of infrastructure. One participant of the focus group discussion in Chiredzi stated that: *"The lack of timely access to accurate climate information hinders our planning and decision-making processes."* (CCWM9, September 2020)

Moreover, another IMC member at Mahlaba community garden from Zvishavane commented: *"Challenges with accessing funding for operation and maintenance of our water sources including the need for dam scooping is affecting our water storage and reducing irrigation opportunities in this village."* (ZCWM1, February 2021)

Field observation in Zvishavane revealed that the Mahlaba dam (Plate 4.1) was affected by siltation, and its water holding capacity was reduced. Catchment management and dam scooping funding were identified as needs for rehabilitation of this supplementary dam.

Furthermore, results from the study's field observations of Dendere and Rupangwana irrigation schemes indicated that infield water management practices required some improvement. Leakages and unattended breached infield canals resulted in water loss and wastage (Plate 4.2).

Plate 4.1 Heavily Silted Mahlaba Dam
Source*: Author, December 2020*

Despite focusing on water governance issues, results from the study indicated that smallholder farmers need to do more work on catchment and infield water management practices to achieve climate-compatible water resources management.

Plate 4.2 Infield water leakages at Rupangwana irrigation.
Source*: Author, November 2020*

b) Water Point Committee (WPC)

Results from the research revealed the existence of Water Point Committees (WPC), which are voluntary village-based structures set up by smallholder farmers as the focal point committee responsible for daily managing public water points. Both key informant interviews with water technicians from DDF and the findings of the focus group discussions indicated that the detailed roles of water point committees include:

i. Protect water point (borehole, deep, shallow wells, springs, and communal tapes), including maintaining hygienic practices
ii. Organize water management meetings
iii. Fix minor breakdowns and reporting major maintenance or rehabilitation needs to Village Pump Minders (VPM) and DDF.
iv. Implement the local level water use guidelines per the local level group constitution.

v. Maintain a water point fund by collecting fees for maintenance and subscriptions where applicable.

vi. Facilitate the enforcement of payments and collection of borehole breakdown fees for covering community-led maintenance costs.

In view of the institutional roles above, it was key to determine the extent to which these duties are fully implemented and the reasons behind any failure in the implementation of the roles. Some water point committees indicated that they were not executing their duties fully. This resulted in poor service delivery, unattended breakdowns and overall water challenges, including conflicts between smallholder farmers and other users. The study further revealed that there was a larger proportion of trained than untrained members of the water point committee in both Chiredzi and Zvishavane districts, with the Chiredzi district having recorded more trained members (78 percent) than the Zvishavane district (66 percent) (Figure 4.25).

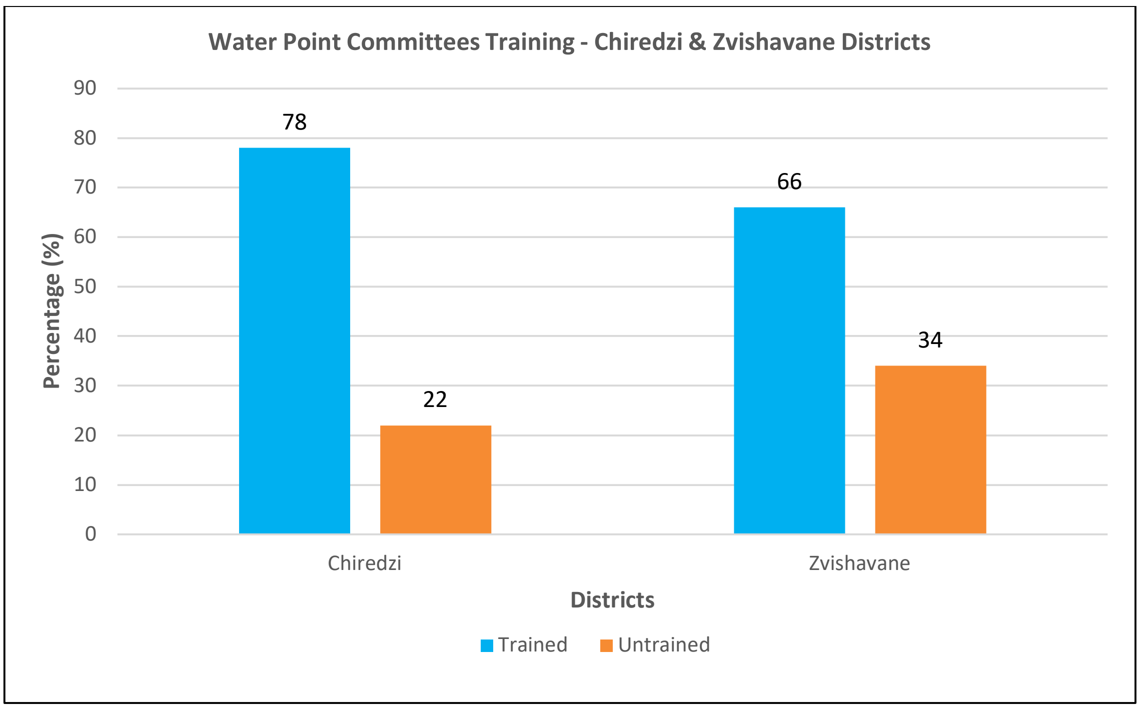

Figure 4.25 Water Point Committee training
***Source**: Author, 2021*

The results from Figure 4.25 above helped to explain the differences between the proportion of the number of functional boreholes in Zvishavane (Table 4.1) and Chiredzi (Table 4.2). Chiredzi recorded more functional boreholes than Zvishavane, which may be related to the training aspect where Chiredzi committee members who received training were more than those of the Zvishavane district.

The research findings revealed some gaps between the mandate and on-the-ground practices by water point committees. Some of the gaps identified are as follows:

i. Lack of a fund for operation and maintenance.
ii. Absence of constitution and guidelines for water point management.
iii. Poor record keeping and absence of water point registers.
iv. Lack of training for new members.
v. No systematic monitoring of water levels.
vi. Absence of committees to manage and maintain water resources.

In view of the above identified gaps linked to the roles of water point committees, the results further indicated some lack of efficiency and conservation in water management and hygiene at some of the visited water points. In ward 2 of the Chiredzi district, the water point (Plate 4.3) was not fully maintained as wastewater from the borehole was not collected hygienically.

Plate 4.3 Water point management at Ward 2 in Chiredzi
Source*: Author, October 2020*

c) Dip Tank Committee (DTC)

The study's findings indicated that dip tank committees dry areas of the Chiredzi and Zvishavane districts played key livelihoods and economic roles by supporting smallholder farmers who own livestock. Besides managing animal health issues, the role played by dip tank committees was identified by the study as inclusive of water management since dipping cattle depends on fresh water. Some of the roles of the dip tank committees revealed by the study include:

i. Managing cattle dipping and dip tank governance.
ii. Spearheading operation and maintenance whenever the need arises.
iii. Mobilizing farmers for planning and works coordination around dipping programmes.
iv. Collecting livestock levies and forwarding them to the government's Veterinary Services Department.
v. Resolving conflict in relation to dipping programme for livestock.
vi. Managing acaricides and other dipping chemicals in liaison with extension services.
vii. Taking stock of the livestock population within the dip tank catchment and report to relevant authorities.
viii. Controlling animal diseases by reporting cases of diseases to authorities.
ix. Managing water collection schedules by farmers for filling dip tanks.

In view of the above roles, one female member of the dip tank committee who responded in the FGD reacted to the discussion on climate change and the impact on the cattle dipping programmes and commented saying: *"As you have heard by the group that animal diseases are increasing, it is because of the challenges we face is that our animals are not dipping on time. I can attribute this to climate change, which has made it difficult for us to get water for dipping our cattle. Our dip tank used to rely on water from the Mkwasine River that used to be perennial, but now it is dry and only flows during the rainy season."* (CCWM7, October 2020)

Results from the study further revealed that governance issues required attention since all dip tanks were not managed effectively by any form of constitution. Clear guidelines agreed upon by the users and authorities were lacking, as identified by committees managing dip tanks in the Mazvihwa and Muteyo communities of Zvishavane and Chiredzi, respectively.

d) Village Pump Minders (VPM)

In view of the complex nature of institutional arrangements offering climate-compatible smallholder water resources management, the study identified village pump minders as key in managing rural water supply systems. Village Pump Minders are local voluntary technical personnel capacitated by DDF to offer borehole repair and maintenance services at the community level. Results from the interviews with key informants and FGDs revealed key roles and responsibilities for the VPM. Some of these include:

i. Providing routine operation and maintenance support for community boreholes.
ii. Receiving breakdown information from their catchment areas.
iii. Coordinating repair and rehabilitate the boreholes.
iv. Compiling reports and communicate with DDF at the district level.
v. Offering advisory services to the community on the daily use and maintenance to ensure boreholes sustainability.

Results indicated that some barriers constrained the village pump minders, reducing their capacity to deliver on their duties effectively. Some of the barriers and capacity gaps identified include:

i. Gender imbalances. The VPM is male dominated even though women are the most users of water resources and therefore need to be capacitated to carry out repairs and maintenance.
ii. Mobility constraints. The results indicated that the distance walked by VPM stretches to over 22 kilometres from one end to the other end of the catchment area. This was the reason behind the reduced borehole rehabilitation and maintenance coverage.
iii. Motivation and incentives are lacking for the support of VPM, which offers voluntary community borehole repairs and rehabilitation. Results from a key informant with District Water Technicians of the two districts indicated that pump minders' toolkits and protective clothing were reported to have lived beyond their life expectance and are a hazard to users. It was reported that the toolkits were provided to all the trained VPMs by DDF, but the supplies were stopped some years ago. Most of the VPM interviewed indicated that they offer community service with limited to no access to personal protective materials.
iv. Ageing of the trained VPM was raised as a growing concern in most communities. As the younger age group was reported to prefer greener pastures in cities and neighbouring

countries, there was a growing concern among the interviewed water users that enrolling members into this voluntary structure is increasingly becoming difficult.

v. The maximum coverage of a VPM, on average, is extremely above the expected thresholds and standards. This meant the team was overloaded and could not efficiently provide full services to their communities. This was supported by Figure 4.26, which presented the VPM caseloads by the district against the maximum recommended standard.

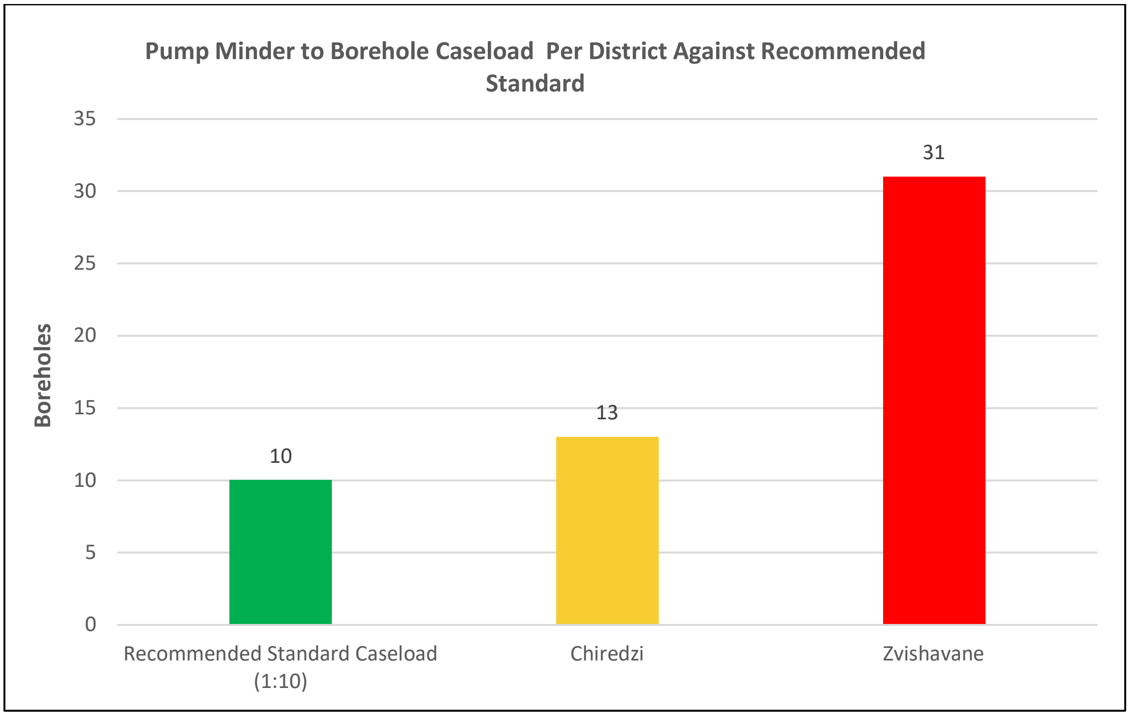

Figure 4.26 Village Pump Minders Caseloads in Chiredzi and Zvishavane districts
***Source**: Author, 2021*

According to the District Water Technicians interviewed, one (1) village pump minder (VPM) is recommended by the standards to service an average of ten (10) boreholes within the defined catchment area. However, the study revealed that Chiredzi district's pump minders have an average of 30 percent extra burden over their caseload in borehole service and maintenance. The same results further pointed out that the Zvishavane pump minders have a 210 percent extra caseload in borehole services and maintenance, as indicated in Figure 4.26.

When asked to confirm the higher caseloads, village pump minders (VPM) in Zvishavane district's wards 15, 16 and 17 reported that their catchment areas have huge coverage with a total of 54, 46 and 42 boreholes against the standard recommendations of 10 boreholes per one village pump minder. Due to extensive coverage, some boreholes remain unattended if community members do not take action to fundraise for their repairs and maintenance and cover the VPM's transport allowances.

4.3.2 INSTITUTIONAL GAPS IN CLIMATE-COMPATIBLE WATER MANAGEMENT

In view of the identified institutional roles and capacities, it was important for the study to establish existing institutional gaps within smallholder water management and the changing climate. Results from the study indicated gaps existed in cases where there were unmet needs in climate-compatible smallholder water resources management. The study's findings revealed that key institutional gaps existed. These were linked to private sector service providers, local public media and information services, decentralized scientific weather and climate information services, and local architectural services, all required to ensure smallholder farmers achieve climate-compatible water resources management. The following section presented these findings:

i. PRIVATE SECTOR SERVICE PROVIDER

The findings of this study revealed the lack of vibrant and sustainable private sector support models in line with climate-compatible smallholder water management. The private sector players mentioned during the study provided short-term engagement and services to communities under the invitation and presence of government and NGO programmes. Services provided were tender or contracts based as commented by a member of the IMC: *"Private businesses mainly offer borehole drilling and water pumping systems when they get contracts from the donor, other businesses and government projects. It occurs only in few and exceptional cases where farmers contract the private sector companies because of financial challenges."* (CLEP8, October 2020)

The study's results noted the gaps in insurance coverage despite growing climate risks and low uptake in renewable energy, technology, and equipment. When probed about the possible causes, smallholder farmer questionnaires and key informant interview respondents indicated that these existed due to the increasing economic challenges that resulted in shrinking space for private sector players to offer good services to the communities.

ii. LOCAL PUBLIC MEDIA AND INFORMATION SERVICES

The study further revealed that access to public media and information services was a gap that reinforced climate change and smallholder water management challenges in both Chiredzi and Zvishavane districts. Most smallholder farmers indicated other means when asked about sources of climate change-related information. They highlighted that there was a need for improving coverage of the television and radio services, as one respondent from Chiredzi's Ndali areas was quoted saying: *"When information reaches our community, it will be in the past, not the current state. Sometimes it will never reach us, and we remain in the dark because our community has no radio and television reception."* (CHR167, September 2020)

And another commented: *"Our area does not receive national broadcasting services for both radio and television. Our radios connect the Mozambican and South African channels. If this remains unsolved, our community will remain marginalized and not move simultaneously with the national development and policy changes."* (CHR175, September 2020)

iii. DECENTRALIZED SCIENTIFIC WEATHER AND CLIMATE INFORMATION SERVICE

Results of the study indicated that Chiredzi and Zvishavane districts have one official weather station, each operated by Meteorological Services Department (Figure 4.27). Buffalo Range airport and Zvishavane's Brange airport are the two weather stations that provide weather and climate information for the two districts. These weather stations were located close to the two towns (Chiredzi and Zvishavane) without other substations, making weather and climatic representation for smallholder farmers in all corners of the districts a difficulty. These two stations are part of the 103 meteorological stations distributed across Zimbabwe, providing service to the country's 390,757 square kilometres (ZIMSTAT, 2016b).

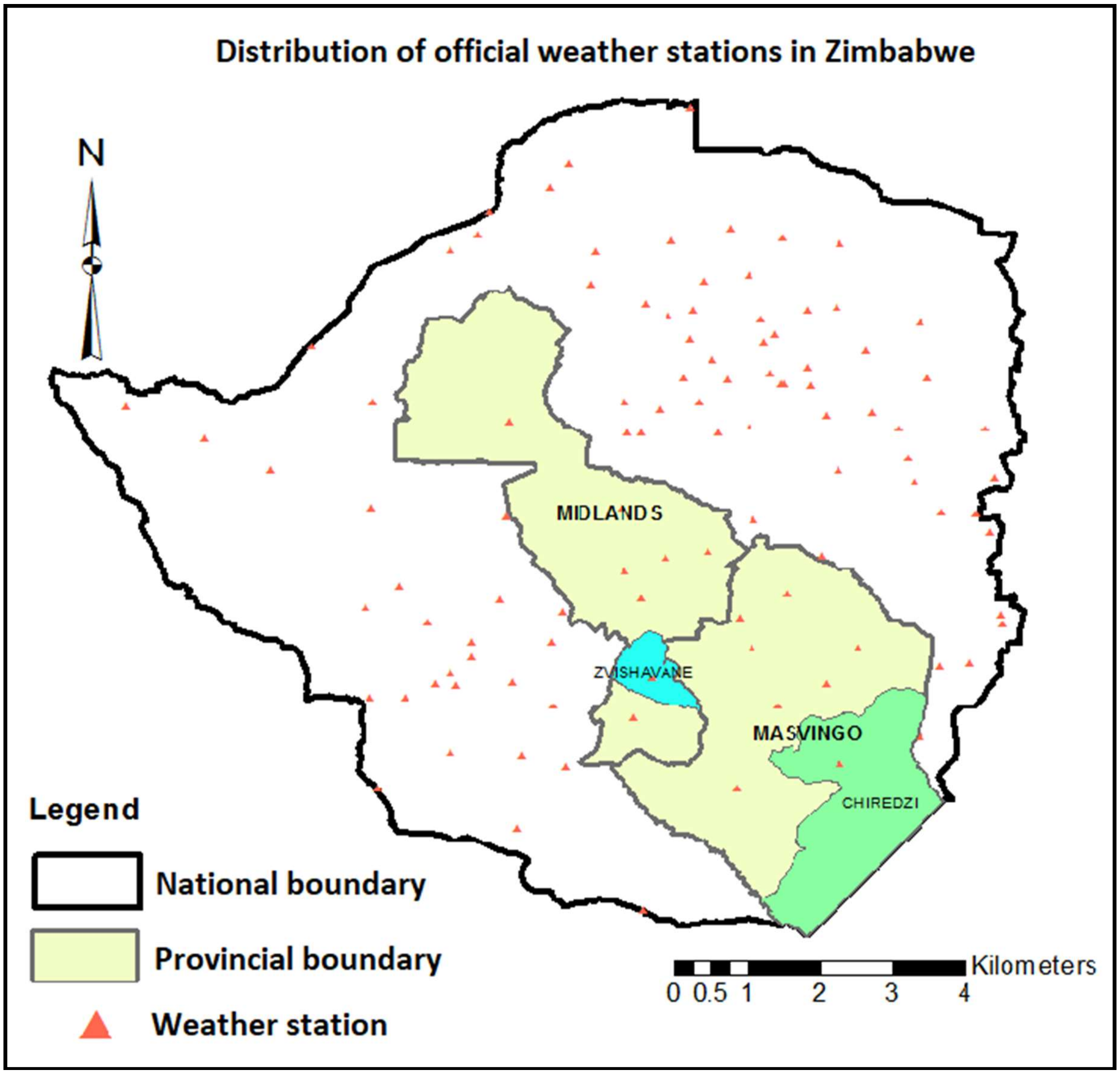

Figure 4.27 Distribution of official weather stations in Zimbabwe.
***Source**: Author, 2021*

The study noted the following challenges due to the lack of decentralized and adequate meteorological stations:

a) Lack of climate and weather updates required for decision making by smallholder farmers whose social and economic development activities are weather and climate indexed.
b) Lack of participation by smallholder farmers in the co-authorship of scientific weather and climate products required for planning and decision-making.
c) The cost of acquiring climate information is exorbitant since climate and weather information is centralized.
d) Limited integration of local indigenous knowledge systems (IKS) available in communities with the scientific information systems, making such community-generated information divorced from the main trusted scientific information.

When interviewed about the way forward in decentralizing climatic and weather information services, the extension officer from AGRITEX concurred with a focus group discussion participant from the DRR committee that smallholder farmers require involvement in generating climate information that they consume. Participants from the Dendere irrigation scheme concurred that they must be capacitated in setting up community-based weather stations, at least at every ward level.

iv. LOCAL ARCHITECTURAL SERVICES

In connection with the results of water sources functionality presented in tables 4.1 and 4.2, the study's results indicated that the age and deep wells that collapsed in the Chiredzi and Zvishavane districts might suggest a depreciation and loss of skills within the local architectures. The research indicated that a well-constructed in 1948 in Chiredzi is still intact compared to the collapsed well of the year 2013. The same scenario was recorded by the results in Zvishavane, where the two wells constructed in 1927 and 1943 are still functional compared to the 2013 and 2016 constructed wells that collapsed. In the Chiredzi district, some of the oldest deep wells were lined with stones in an architectural fashion that stabilized the well against collapsing. A focus group discussion with the Water Point Committee members at Ndali revealed that the past generations did the resilient architecture. The participants indicated that the community had very few and very old architects who could not attend to all the work. The number of collapsed and unrehabilitated deep wells was therefore linked to the absence and shortage of local architecture.

The study's results further revealed that the existing institution within the Village Pump Minders was only trained and capacitated in maintaining the B-type bush pump boreholes. The interviewed pump minders revealed that they were trained on mechanical aspects based on B-type pumps and had no capacity for well construction and rehabilitation.

4.4 STRATEGIES TO IMPROVE CLIMATE-COMPATIBLE SMALLHOLDER WATER MANAGEMENT IN DRYLANDS

In view of the above observations that were in line with the first and second objectives, it was therefore important for the study to establish strategies to improve climate-compatible smallholder water management in drylands as these were useful anchors in supporting rural livelihoods through water management for communities in rainfall marginal areas. Through triangulating various information gathered from household questionnaires, KIIs, direct measurements, secondary data sources and FGDs, the study presented the findings in line with the third objective on strategies to improve climate-compatible smallholder water management in dry areas. The study's findings on climate-compatible smallholder water management strategies/instruments were therefore categorized into governance, behaviour change, water resource conservation, water source rehabilitation, water replenishment and development, and risk management strategies, as detailed below.

4.4.1 GOVERNANCE INSTRUMENTS FOR WATER RESOURCES

In view of the intertwining socio-economic, environmental, political, and administrative competencies within rural smallholder water management context, it was interesting for the study to establish the governance instruments that enabled or constrained water use and management by smallholder farmers in dry lands. The findings from the study revealed the existence of a basket of governance instruments for water management. In connection to climate change impacts identified in section 4.1.2, KII and FGD participants from Chiredzi and Zvishavane districts concurred that governance instruments and strategies can provide opportunities for improving climate-compatible water management. A participant from the Timba group water point committee commented that:
"We investigated the reason behind the water crisis at our solar-powered water system and realized that some of the members of our communities were coming and stealing water with drums, emptying the reservoir at night. Our constitution was drafted and had binding clauses and penalties for such acts. We can share our water equitably throughout the peak dry period." (ZCWM2, March 2021)

In the Chiredzi district, a member of the water point committee at the Muteyo area was also quoted reiterating the governance-related water use and management views, saying: *"Between August and December yearly, every household reduces the area under irrigation until we receive the next rainfall. The key priority for water use becomes drinking by the people and livestock."* (CCWM11, November 2020)

After observing on-the-ground practices and listening to the different stories and experiences, the study gathered that the following governance-related instruments were all necessary for sustaining water resources:

i. Access and maintenance fee payments helped certain groups to maintain their water infrastructure. Although a few individuals maintained this water fund at the local level, it was highly recommended for adoption to increase community ownership and sustainability for the infrastructure.
ii. The confined water use approach, which limits water use to critical life and ecosystem support functions, was a necessary compromise that key informant interview participants recommended as a measure for managing water crises. This was noted in the Mazvihwa area, where the use of boreholes and well water sources for brick moulding was barred by authorities to ensure water remained available for critical life and ecosystem support.
iii. The role of traditional leaders and indigenous knowledge systems was recommended to be strengthened as per the Traditional Leaders Act, Chapter 29:17 and the Rural District Council Act, Chapter 29:13, which gave mandates over conservation of natural resources within the village's jurisdiction to the village heads and guided the formation of development committees at village and ward levels.
iv. The adoption of a water point maintenance register was proposed as a tool for recording the population of users, their contribution to the maintenance works, and scheduling planning sessions to inform decision-making and management plans.

4.4.2 BEHAVIOUR CHANGE STRATEGIES TOWARDS WATER RESOURCES

The study's results indicated that behaviour change was a necessary tool in managing water resources in rainfall marginal areas with various competing water uses. One key element of behaviour change is awareness. The study indicated that limited sources of climate information were used by communities in marginalized areas, including the Chiredzi district. The public media was reported to have low coverage of 28 percent despite being the most effective. Smallholder farmers relied on local extension officers whose coverage was 61 percent in disseminating climate information. When probed about whether they were trained to offer communication products to the farmers, the key informants from extension services indicated a gap and required training.

Based on their lived experiences, the smallholder farmers who responded felt that water management in drylands required behaviour change. During a Focus Group Discussion with DRR Committee, IMC, and WPC in Chiredzi, one female participant was quoted commenting: *"Our climate has changed. We have felt the heat, and our water resources are no longer sufficient for our needs. We need more relevant information to help us plan and prepare early if any disaster is coming."* (CCWM8, September 2020)

4.4.3 WATER RESOURCES CONSERVATION STRATEGIES

In connection with the identified competing water uses, the results of this study revealed that conservation practices were some of the strategies for enhancing climate-compatible water resource management. Different conservation practices were identified to be constrained by land tenure. Through probing key informant Interview participants, the study revealed that smallholder farmers without secure and unclear land tenure had no motivation for soil and water conservation adoption. In Zvishavane and Chiredzi district's study areas, the land tenure system was the "Occupancy Right to Land in Communal Areas", which was very secure and allowed smallholder farmers to invest in their water resources. Based on field observations, smallholder farmers were seen practising different infield water conservation measures that kept the farms moist, and these include:

i. Infiltration pits, also popularly known as "*zvikodobo*" in the Mazvihwa area in the local language.
ii. Half-moon pits, also known as "*Zai pits*" in Chiredzi and Zvishavane
iii. Tied ridges, also known as "*makandiwa*" in Zvishavane

Other water conservation practices adopted by smallholder farmers include wetlands and spring protection, reclamation of wastewater from boreholes into a water trough for watering livestock or irrigation. The major gap identified by the research in water conservation includes the absence of mechanical equipment for use in scaling up conservation works. The use of small primitive tools like handheld hoes was said to be slow, unsustainable, and inefficient. Participants pointed out the successes they witnessed in using tractors to conserve soil moisture. Based on the communities' lived experiences, policies and institutional linkages were identified as areas of investment and leverage as they proved to reduce water demand.

4.4.4 WATER SOURCE REHABILITATION STRATEGIES

In line with the results on the proportion of water points that were reported to be partially functional (24.4%), collapsed (5.1%) and not functional (14.1%), as indicated in table 4.1, the KII and FGD participants revealed that water source rehabilitation was critical for the achievement of climate compatible water resources management. When asked about the key programmes and players in water source rehabilitation, the groups from Dendere irrigation and Mahlaba garden pointed out that development partners and government were key providers of financial, technical and equipment for the processes involved in water source rehabilitation works. The study identified some commonalities in benefits accrued from water source rehabilitation in both districts as follows:

i. Dam scooping may increase the water storage capacity for the reservoirs
ii. Equipment supplied by the rural WASH programme jointly implemented by UNICEF and the government was important in reviving partially and non-functional boreholes.
iii. Well-deepening, mud scooping, and lining programmes were important in ensuring access to clean water by communities in dry areas.
iv. Fencing of water points was identified as a vehicle for improved hygiene, sanitation, misuse, and reduced vandalism of water infrastructure.

In line with the study's results, which indicated that springs and wetlands in the Zvishavane district were rated moderate yielding (69 percent), rehabilitation activities for these public assets were identified as a major need. One participant in the focus group discussion commented that: *"Despite all these successes noted in rehabilitation works, our wetlands water sources are at risk from livestock trampling."* (ZHR161, January 2021)

Figure 4.28, presented in the following section, provided indications of the hydrological formation within the Zvishavane's Marirangwe wetland. The shrinking and drying surfaces were identified in Figure 4.28, where the colour of the profile between zero (0) and 15 metres vertically indicated a compacted and hard surface which was black, representing a depleted water zone and yellowish, representing semi-impervious material due to compaction, effects by livestock.

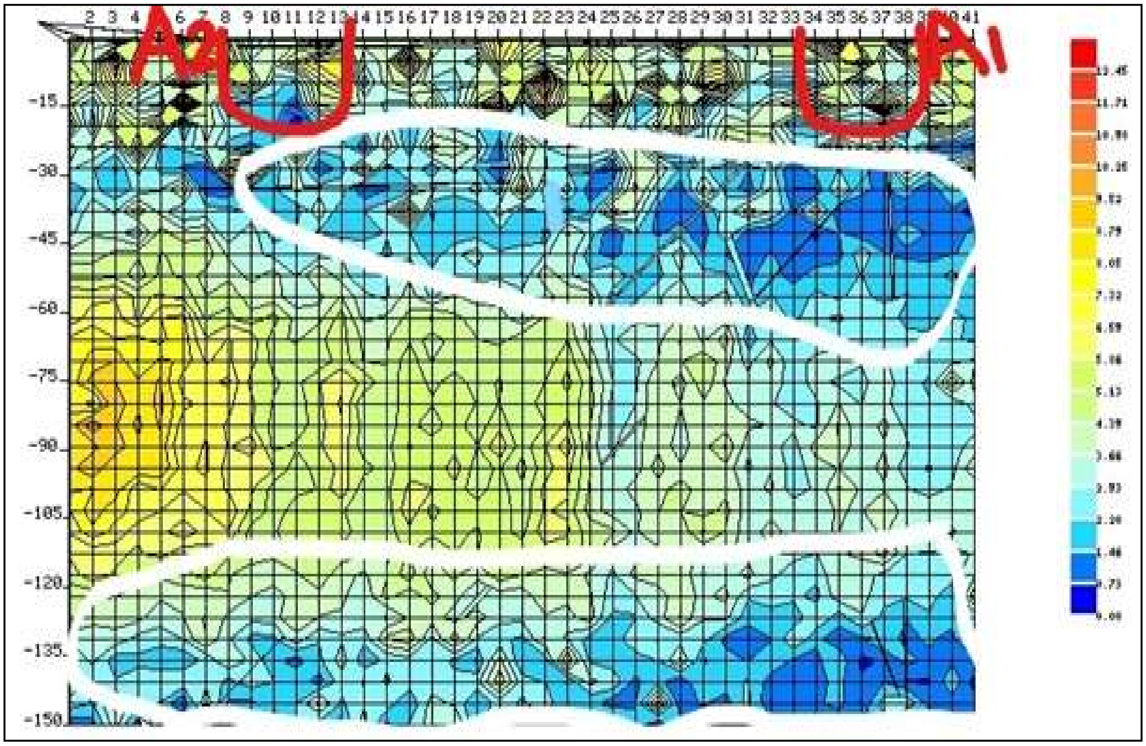

Figure 4.28 Marriage wetland's hydrogeological profile, Mazvihwa, Zvishavane district
***Source**: Author, September 2020*

The analysis of the formation pointed to the complex nature of the sub-surface water-bearing aquifer that required holistic management and rehabilitation due to the interconnectedness in groundwater flow within a wetland. Two open water sources (wells dug) within the wetlands (A1 and A2) were mapped and delineated. With only a distance of 30 metres apart, the water sources used by the community proved to be interconnected with sub-surface water flow. The study further analyzed the state of the wetland using geological and ecological indicators and identified that it was degrading and required significant rehabilitation to ensure the community realizes continued benefits.

4.4.5 WATER REPLENISHMENT AND DEVELOPMENT STRATEGIES

In connection to climate change-induced water challenges noted by the study, different efforts related to water replenishment and new sources development were identified as part of a community of practice in water-stressed areas. Different efforts noted included those focused at the watershed level, river basins, hydrogeological aquifers, micro catchments, farms, and at household unit. Through FGDs and KIIs, the study identified the following strategies:

i. Rainwater harvesting is also known as rooftop catchments. The community indicated this was only viable for households with zinc and asbestos roofed structures. The viability of the roof catchment was discussed at length. One striking aspect agreed by respondents is that the size of water storage needed to be increased to enable long-term water storage during and after the rain.
ii. Surface water storage replenishment through the construction of dams and weirs was noted as an important strategy. Participants of the key informant interview in Chiredzi and Zvishavane's Mazvihwa area indicated that dams were critical for livelihoods and ecosystems in dry areas. Most community members expressed the need to increase the number and size of dams to ensure their community can harvest large volumes of water to avert drought conditions. Results indicated that the construction of large dams was viable in the Chiredzi district, where the key informant interviews noted the Save River catchment that drained around 43,494 square kilometres. It was further revealed that the water that passes through Save River was flowing from Odzi River in Eastern highlands areas that receive an average of 1,200mm of rainfall per year, Furtherstone and Marondera areas that receive an average of 600 mm of rainfall per year. The study also indicated that the Save River flows for over 400 kilometres until its confluence with the Runde River and crosses to Mozambique, where it discharges water into the Indian Ocean. The volume of Save River flow makes dam construction a viable project in the Chiredzi district.
iii. Groundwater recharge enhancement activities were noted as these encourage infiltration more than surface runoff. They were more related to the conservation measures like wetlands protection, infiltration pits and micro basins in the farms and rangelands. Groundwater development was identified as a growing opportunity for new water sources. The drive for upgrading high-yielding boreholes with solar-powered pumping and piped water systems to replenish more households with enough water was noted as a best practice. Solar-powered piped water schemes were increasingly becoming more common in Chiredzi and Zvishavane districts. Communities preferred solar-powered water pumping technology for boreholes to the mechanical B-type bush pumps associated with labour-intensive water pumping. A key informant indicated that solar-powered piped water schemes were preferred when considering the role of women and girls in providing water for households and agriculture.

To understand the groundwater potential for Chiredzi and Zvishavane districts, the study used ArcGIS 10.5 to produce hydrogeological maps of the two districts (Figure 4.29). Through hydrogeological mapping, the results indicated that the Chiredzi district has high-yielding aquifers within the Save alluvium. When further confirmation was done through PQWT groundwater mapping, the study revealed the existence of large high-yielding aquifers, as presented in Figures 4.10 and 4.30. The study was also interested in getting the actual potential of borehole yield. A capacity testing exercise for the Ndali borehole was conducted for over 12 hours using a 2-horsepower pump. Results further revealed that the boreholes drilled in Save Valley Alluvium, a Sedimentary Intergranular/Fractured aquifer (Ó Dochartaigh, 2019), had an average of 10,800 litres per hour during the dry period.

The results indicative of abundant groundwater resources from the direct hydrogeological survey and aquifer mapping in the Chiredzi district were further supported by members of water point committees who commented saying: *"Our boreholes have plenty of water. The past droughts, including 1992, 2016 and 2019, failed to deplete the water table from this village borehole. All people and animals were drinking from this water source."* (CCWM10, November 2020)

Contrary to the Chiredzi district, the Zvishavane district had an underlying Basement aquifer with low fractures and very low yields. Key informant interviews revealed cases of drying borehole during peak dry season. Most boreholes were reported to be intermittent and providing water only during and soon after the rainy season. One community member was quoted saying: *"We need drilling of more boreholes to revive the dying agriculture."* (ZHR160, February 2021)

Furthermore, the District Water Technician revealed that groundwater in Zvishavane district is increasingly becoming more scarce in some areas and commented that: *“This area is very dry. We have tried to drill boreholes as deep as 120 metres many times but failed to get water in most cases."* (ZGVT6, March 2021)

A member of the Village Pump Minders also echoed the same sentiments about challenges in successfully drilling groundwater saying: *“Borehole drilling in this Ward is associated with failure and is, therefore, a waste of resources."* (ZCWM5, March 2021)

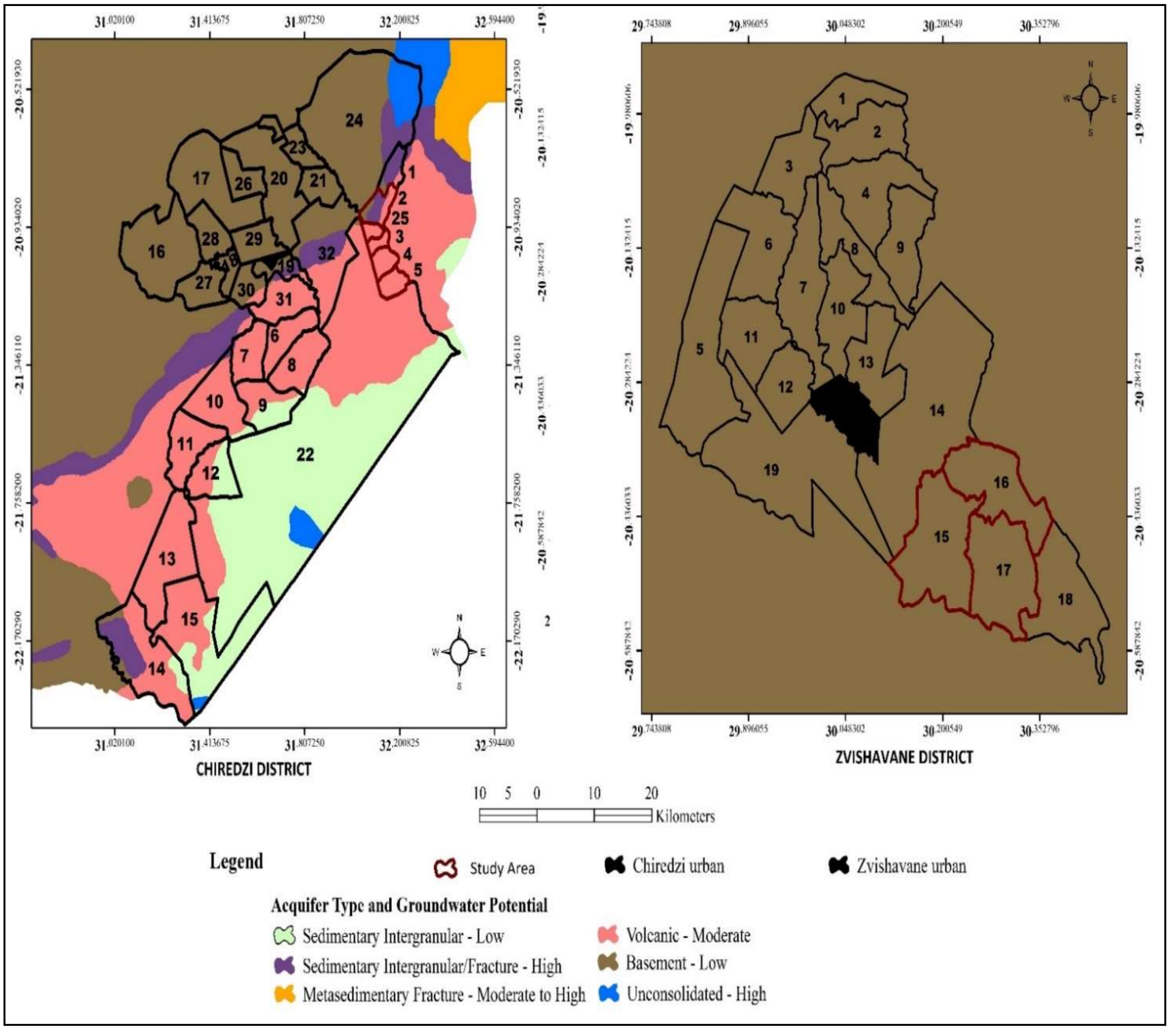

Figure 4.29 Hydrogeological maps for Chiredzi and Zvishavane districts
Shapefile Source*: British Geological Survey (2019)*

Finally, the Ward Councillor in Zvishavane's Runde Rural District Council indicated that due to poor borehole drilling success rate, some of the wards are not prioritised for borehole drilling to to increasing financial risk associated with failure to get water. The Councillor was quoted saying: *"Our council do not prioritize drilling of boreholes in this ward because the ward is rocky and has very limited potential for successful boreholes."* (ZLCL2, December 2020)

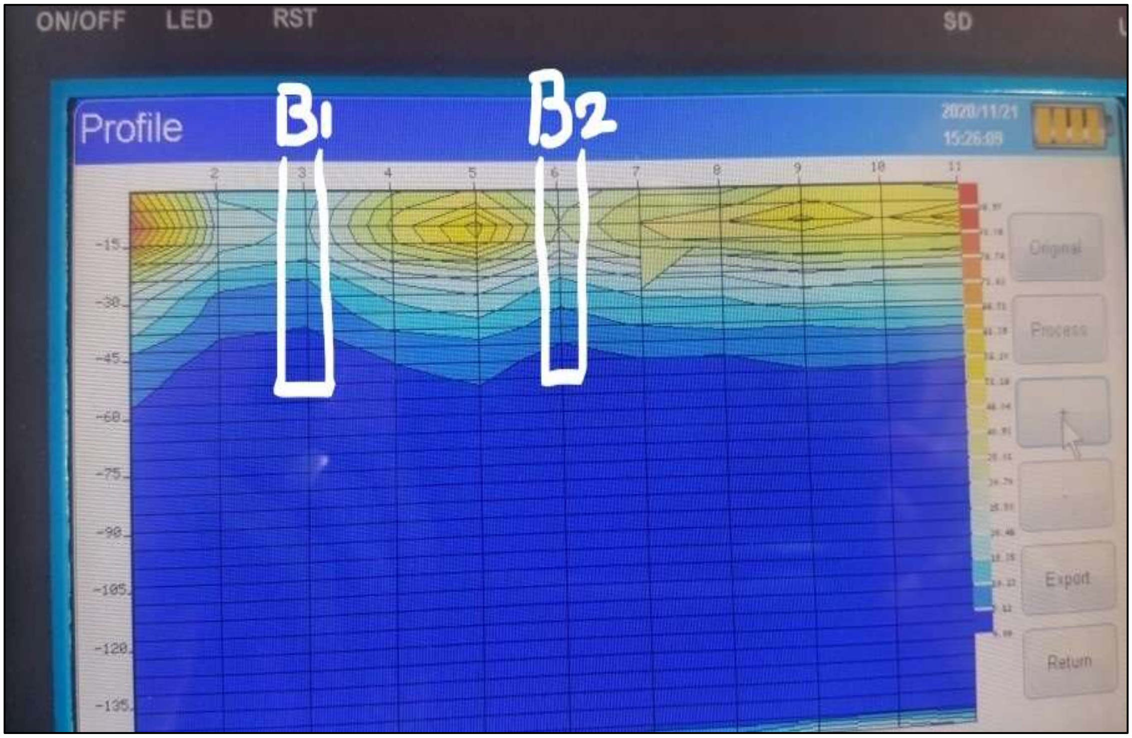

Figure 4.30 Save alluvium aquifer hydrogeological profile
***Source**: Author, September 2020*

Water replenishment and development strategies were therefore recommended to consider the different water source potentials. For the Chiredzi district, high potential was noted for surface water harvesting, groundwater development and replenishment. In the Zvishavane district, more replenishment activities were considered viable in micro catchments, soil moisture, watershed and catchment approaches.

4.4.6 RISK MANAGEMENT STRATEGIES

The research revealed that smallholder farmers in the dry lands of Chiredzi and Zvishavane were vulnerable to drought and floods that disrupted their livelihoods over the years. These challenges were noted to be on the sharp increase. Communities in the study areas outsourced most of their risk management to the government, development organizations, and humanitarian partners. Results from the analysis of coping strategies employed against climate change and economic-related shocks and stressors indicated that communities had very little to no capacity to cushion themselves, as presented in Table 4.9.

Table 4.9 Smallholder farmers' risk management against historic shocks

Year	Shocks	Impact	Risk Management
1982/83	Drought	Food and water insecurity. Livestock deaths	Government social support
1987	Hailstorm	Crop and housing damages	Government social support mechanism
1991	Economic Structural Adjustment Programme (ESAP)	Employees were retrenched, and some relocated to rural areas. Income loss	Poor livelihood coping strategies by communities
1992	Drought	Food and water insecurity. Shortage of pastures and water	Government support.
1997	Drought, Problem Animal Control	Food and water insecurity. Shortage of pastures and water. Spread of animal diseases.	Government social assistance programme
2000	Cyclone Eline	Loss of livestock, crops damaged, housing units destroyed, deaths	Humanitarian organizations and government support
2002	Drought. Problem Animal Control	Food and water insecurity. Shortage of pastures and water. Spread of animal diseases.	Humanitarian support increased. Government support programmes.
2007	Anthrax	Spread of animal diseases, animal deaths increased	Government and donor veterinary support
2008	Drought, Hyperinflation	Unavailability of basic commodities in the country, food insecurity, and water access challenges	Basic Commodity Support Initiative (BACOSI) by the government through the central bank. Borehole drilling by donors.
2009	Drought, Cholera, Problem Animal Control	Food and water insecurity. Shortage of pastures and water. Spread of animal diseases.	Intensified humanitarian support by donors and aid organizations
2010	Cholera, Problem Animal Control	Health problems and deaths increased for humans and animals	Government and aid organizations provided support.
2011	Drought, Heatwave temperature reached 49^{o}C, killing birds and animals	Shortage of food and water. Deaths of animals and depletion of pastures	Government and donor aid support rolled out in affected communities

2012	Drought	Food and water shortages, economic challenges	Government and humanitarian support
2013	Problem Animal Control	Spread of zoonotic diseases from parks to livestock and people.	Government and aid organizations provided support.
2016	Drought	Food and water shortages, economic challenges.	Government and humanitarian emergency support increased
2017	Fall Army Worm (FAW) outbreak	Massive destruction of crops and reduction of yields	Government, development organizations and researchers offered response programmes
2019	Cyclone IDAI, Drought	Shortage of food and water. Deaths of animals and depletion of pastures	Emergency humanitarian support by government and aid organizations increased

Source*: Author, 2021*

Results (Table 4.9) indicated that most of the support offered to stressed communities was from the central government and humanitarian aid organizations. When probed about the mechanisms that communities may adopt to ensure they have sustainable risk management practices, two focus group discussions with DRR committees indicated that tailor-made products with the capacity to provide response mechanisms against shocks based on the seasonality of water supply and demand were ideal. Considering the losses incurred by smallholder farmers on crops, livestock and erosion of accumulated productive assets, the participants proposed adopting any tailor-made insurance model that may spread risk away from the smallholder farmers.

4.5 CONCLUSION

In conclusion, this study's results and findings were presented, reflecting on the research questions. Key findings presented in this chapter include the opportunities and constraints associated with climate change on smallholder water resources. The findings on the existence and the role played by local institutions, and the strategies that can be adopted for improving climate-compatible water resources management were some of the results presented in this chapter. The following section, Chapter 5, presents the discussion and analysis of the study in line with the presented empirical evidence, the methodology used, and the literature reviewed as detailed in previous chapters.

CHAPTER FIVE

DISCUSSION AND ANALYSIS

5.1 INTRODUCTION

This chapter discussed the key findings of the research, including detailed discussions on the implications of the study's findings. Results indicated that different opportunities exist for the benefit of smallholder farmers. At the same time, constraints required several strategies to ensure that smallholder water resources are conserved and sustainably managed under the changing climate, political and economic context. This discussion is organized into seven sections, with the introductory part (section 5.1) being the first. The second section (5.2) discusses key opportunities brought by climate change on smallholder water management in dry areas. In contrast, section 5.3 discusses findings on climate change-related constraints and their impacts on smallholder water management in dry areas. A discussion on the roles, contributions and barriers within local climate change and water management institutional arrangements was presented in section 5.4, while section 5.5 discussed key strategies for climate-compatible water management in dry areas. A proposed "**Systems Based Resilient Water Management Framework**" was presented and discussed in section 5.6. Finally, a conclusion section of this chapter was presented in section 5.7, which gave an overview of the discussion chapter and pointers to Chapter 6, presenting the Conclusion and Recommendation.

5.2 KEY OPPORTUNITIES BROUGHT BY CLIMATE CHANGE ON SMALLHOLDER WATER RESOURCES IN DRY AREAS

The study found that the impact of climate change and variability on smallholder water resources were associated with fewer opportunities than challenges. Some of the key opportunities were discussed in-depth in this section. These include water harvesting, funding, partnership, capacitating and strengthening of local institutions, climate and weather information services improvement, technological and knowledge transfer benefits, and policy, programmes and practice improvements.

Evidence from this study revealed an increasing number of smallholder farmers who find opportunities from water harvesting as a response to the highly variable and changing rainfall pattern. Participants of the focus group discussions in the Zvishavane and Chiredzi districts agreed that communities increasingly implemented water harvesting in various forms as mitigation and adaptation measures for climate change. Different types of water harvesting techniques were identified. Rooftop catchments, micro basins, infiltration pits, half moon, tied ridges, ground surface or rocks methods, irregular surfaces, diversion ditches and cut-off drains, retention ditches and grass strips that promoted soil moisture conservation and replenishment of water systems. This finding was also in line with Tamagnone et al. (2020). They indicated that rainwater harvesting was increasingly becoming an important solution and opportunity for arid and semi-arid areas facing water scarcity. While it was noted as a challenge that the occurrence of heavy rainfall will increase in frequency, the World Bank Group (2020) further identified it as an opportunity for improving surface water harvesting and groundwater storage replenishment.

The study revealed that after years of consecutive droughts, shallow (rainfed) wells, wetlands and boreholes yields started to decline in both districts. The World Bank Group (2020) projected a more than 50% increase in heavy rainfall compared to the period between 1850 and 1900, with droughts doubling during the same assessment period. Rainwater harvesting opportunity was further identified as a hydrometeorological-based adaptation practice for semi-arid smallholder farmers, as revealed by Ayele (2014), Qadir et al. (2007) and Linderhof et al. (2022). In the Zvishavane district, the work by Zephaniah Maseko Phiri cannot be ignored when discussing successful water harvesting. Phiri's innovations were documented and embraced to increase agricultural and biodiversity productivity in the arid community of Mazvihwa (Muonde Trust, 2022; Oakland Institute, 2009). In line with the principles that led to Phiri’s successes, Tamagnone et al. (2020) indicated that rainwater harvesting can result in 87% retention in runoff water and double the infiltration rate. This extends the growing season by around 20 days due to moisture availability. This is a great opportunity for increasing crop yields in drought-prone areas. However, technology is required to mechanize the practice. It brings efficiency, time, and labour-saving advantages since most rural smallholder farmers were identified as labour and time constrained.

Climate change was associated with the development and increase in new financial support schemes and partnership opportunities. Funding mechanisms including adaptation funding

(Government of Zimbabwe, 2020c) that supported Zimbabwe with USD26.6 million (Green Climate Fund, 2022; Government of Zimbabwe, 2021b) and other financial mechanisms, including GEF Sustainable Forestry Management (FAO, 2020) and UNDP Zimbabwe country programmes (UNDP, 2009a, 2015b) were implemented in line with sustainable development goals, international treaties and agreements. Infrastructure rehabilitation and development and capacitating local smallholder farmers and the private sector was key area of achievement. Chiredzi was identified to have received several funding opportunities, including the UNDP's Coping with Drought and Climate Change (UNDP, 2009b) and Zimbabwe Resilience Building Fund projects (UNDP, 2015b).

The study revealed that the Zvishavane district benefited from UNDP Country programme projects, including the Zimbabwe Resilience Building Fund (Zimbabwe Resilience Building Fund, 2016). The funding was mostly implemented directly by government ministries at the national level, the United Nations, and International NGOs playing a leading role. There is a need for climate change funding to be downscaled and implemented with local actors and communities whose capacities need to be enhanced since they have witnessed and experienced climate change impacts. The current funding mechanisms have not done much in providing the required levels of climate funding finance meant for communities and local authorities. This may also be best explained by Chiriac & Naran (2020), who indicated that developing countries have been receiving less than 10 percent of the global basket of adaptation funding, making it difficult for funding resources to reach the local level management units.

The study findings confirmed that climate change brought opportunities for capacity development and strengthening of local institutions. Besides the formation of new climate change and water institutions, local farmer organizations, weather and climate service providers, and water institutions benefit from capacity-building activities. The research revealed that several strategies were implemented as response plans and mechanisms for climate change adaptation. These include water, drought, wetlands, and agriculture-related policies and frameworks (Government of Zimbabwe, 2012, 2019b, 2020a, 2021). The country high-level commitment by the Zimbabwean President (Mnangagwa, 2021) to international engagement on climate change issues was a great opportunity for the country to strengthen institutional arrangements by creating linkages with the international community. In line with Yegbemey & Each (2021), institutional gaps and deficiencies noted called for serious high-level engagement. The study further joins the call for the recognition and protection of ILK/IKS by Filho et al. (2022) & Mwenge et al. (2021). Their studies concurred with the findings of this research on climate change adaptation roles played by local institutions.

The study identified investments in climate and weather information services and technology as key areas and emerging opportunities receiving more attention than in previous decades. The study also noted the increase in magnitude, unpredictability and damages related to extreme climate and weather-related disasters as an area that requires more attention and timely and accurate information. The current coverage with one meteorological weather station per study area was identified as an area that called for attention. Contrary to Yegbemey & Each (2021), who indicated that mobile phones dominated the channels used to disseminate climate and weather information, the study indicated that extension services personnel who conducted community meetings dominated the dissemination means.

A wide range of weather and climate services include the daily weather report, three (3) days forecasts, ten (10) days forecasts, seasonal forecasts, agro-meteorology and rainfall bulletin, and climate or weather-related advisories and warnings. The results from the focus group discussions (FGDs) indicated that only two services (daily weather report and seasonal forecast) of the total six, sometimes reach the smallholder farmers, depending on the availability and coverage of the media communication. With technological advancement, Unganai et al. (n.d.) pioneered the SMS platform tailor-made for supporting smallholder farmers in semi-arid areas of Zimbabwe. With the scaling up of a voluntary network of weather observation stations, currently, at around 500 in Zimbabwe (Manzou, n.d.; SADC, 2012), there will be greater opportunities for co-production, dissemination and enhanced consumption of weather and climate products. The increased use and coverage of mobile technology reduced costs of internet connectivity, electronic extension (e-extension), social media and digital marketing platforms will be critical in solving weather and climate information challenges. The opportunity for growing local observations is critical in leading local-level planning and developing early warning systems (EWS) and adaptation processes.

The findings from this study revealed key opportunities around improved policy, programmes, and practice. In sync with the United Nations Sustainable Development Goals (SDGs), most programmes and policies, including the national blueprint, the National Development Strategy (NDS) 1 (Government of Zimbabwe, 2021a), were formulated in line with the vision 2030, among other ambitions set at the international and national scale. During fieldwork and data collection, the Key Informant Interview participants and government and local authorities repeatedly mentioned the need for alignment of the climate change-related projects and the strategic direction of the NDS1. Increased awareness of climate change was a key opportunity driving adaptation and mitigation practices among government and local leadership. Key policies that were put in place in response to climate change during the past ten years include the Zimbabwe Climate Policy (Government of Zimbabwe, 2016b), National Water Policy (Government of Zimbabwe, 2012b), policies and frameworks on wetlands (Zimbabwe Wetland Policy, 2020) and other commitments to international policies and programmes (Government of Zimbabwe, 2019a, 2021a, 2021b). A great improvement was noted in the "community of practice", where smallholder farmers and their stakeholders, including extension officers, local authorities, and CBOs, were seen pulling in one direction and concurring on climate-smart and adaptation approaches.

5.3 CLIMATE CHANGE RELATED CONSTRAINTS AND THEIR IMPACTS ON SMALLHOLDER WATER MANAGEMENT IN DRY LANDS

This section discusses climate change and water-related constraints, including the increasing frequency, magnitude and unpredictability of climate and weather extremes. The rising temperatures and changes in rainfall patterns were identified as the major reason for the water deficit and droughts experienced in the Chiredzi and Zvishavane districts. The disruption of ecosystems, increase in the seasonality of water sources, outbreaks of crop pests and animal diseases, and increasing cases of food and nutritional insecurity were some of the climate change-related challenges identified by the study.

Evidence from the research indicated that, as reported by other studies, the frequency, magnitude and unpredictability of extreme weather and climatic events were an escalating challenge for smallholder farming communities. Without access to insurance and other sustainable risk management mechanisms, the communities were identified to be more vulnerable to climate change. They outsourced their risk management to government, development, and humanitarian partners, during droughts, floods, and disease outbreaks. In both Zvishavane and Chiredzi districts, smallholder farmers and key informants indicated that their districts were becoming permanent domains for humanitarian assistance offered by World Food Programme (WFP) under the Lean Season Assistance (LSA) and Food Assistance for Assets (FFA). The study identified smallholder farmers participating in LSA food aid distribution during the data collection period. During the same time, at the onset of the rainfall, several households were reported by the District Civil Protection Unit to be in urgent need of shelter after the storm destroyed their dwelling units and toilets. Climate change impacts were therefore identified to have reversed developmental gains accumulated over time by communities.

The findings from the study indicated that the increase in atmospheric temperature and declining rainfall amounts were worrisome challenges faced by smallholder farmers. A general increase in temperature Fig 4.15 Chiredzi, Fig 4.16 Zvishavane concurred with the national trend (Figure 4.17). However, Chiredzi and Zvishavane's increase was higher than the national average, indicating that the southern districts are more vulnerable than the national average) as revealed by the MK Test (Mazvimavi, 2010). These findings agree with the other findings of the 1990s by Unganai (1996) and more recent studies and reports (UNDP, 2017; Brazier, 2018; Nangombe, 2015; World Meteorological Organization, 2021). The study further noted a decline in rainfall amounts as reported by the smallholder farmers' perception. They depicted the increased vulnerability of water-stressed communities. The rainfall means of the districts were lower than the nation's averages. The statistical insignificance in rainfall changes indicated interannual and interdecadal variations (Mazvimavi, 2010). However, these slight changes in dry land are associated with negative impacts on smallholder farming families' food security and economies. The reduction in rainfall and the concurrent increase in temperature are causes of concern in the Chiredzi and Zvishavane districts, where droughts recurrences have increased and undermined smallholder farmers' water and livelihoods, as revealed by the UNDP (2017).

Evidence from the study suggest that climate change resulted in the disruption of ecosystems, as discovered by Mwenge et al. (2021). The ecosystems in drylands, including forests, shrublands, wetlands, and rivers, are rich biodiversity hotspots and great sources of smallholder farmers' livelihoods. Their disruption means that negative food, water, materials, and availability indicators species are at risk of extinction. According to Mwenge et al. (2021), the disruption of biodiversity hotspots in arid areas consequently disrupted the IKS and ILK that thrive on biophysical indicators like birds, certain vegetation and insect species for seasonal weather and climate forecasts. Disappearances of wetlands threatened wetlands ecosystems, including causing the migration of bird species used as short-term indicators in the seasonal climatic focus by communities in Marirangwe of Mazvihwa area of Zvishavane.

The study revealed that the seasonality of water sources is on the increase. Communities of Timba and Muteyo in Zvishavane and Chiredzi, respectively, indicated that most of their groundwater and rivers, including Gwemombe and Mkwasine, used to provide water to the communities throughout the year, but they are currently flowing intermittently. Differences in groundwater aquifer formations, water table levels, and water management practices between Chiredzi's Ndali and Zvishavane's Timba boreholes were identified as some of the determinants behind the reason why some water sources are perennial. In contrast, others become intermittent under the same climatic conditions. Reduced rainfall and increased temperatures have resulted in increased groundwater withdrawal and dependency on groundwater sources due to climate change-induced water shortages. In a study conducted in Chiredzi by Bowora et al. (2016), the identified low to absence of community-based management of water resources, including the absence of a water point fund, was pointed out as aggravating factors that led to the seasonality of water sources under poor management.

Evidence from the study indicated that the outbreak of crop pests and animal diseases was observed to be on the increase with increasing temperatures and droughts. Over 70% of smallholder farmers pointed out the increase in the outbreak of crop pests and animal diseases in both the Chiredzi and Zvishavane districts. Figure 4.13 indicated that smallholder farmers related climate change to increased natural hazards and shocks, including the outbreak of crop pests and animal diseases. The Zimbabwe Resilience Building Fund (2016), UNDP & Government of Zimbabwe (2017), World Bank (2019), and USAID (2019) indicated that crop pests and animal diseases outbreak were on the increase. New pests like Fall Army Worm (*Spodoptera frugiperda*) and January disease (*Theileriosis)* have threatened to wipe out the crops and national livestock herd since 2015 when the El Nino induced droughts affected the whole country (World Food Programme, 2015).

Due to crop failure and poor harvests induced by climate change, smallholder farmers in dry lands are under serious food and nutritional insecurity threats. The cost of cereals in these areas is much higher than the average since traders import them from other areas and across borders. Almost every participant in the questionnaire survey mentioned food and nutritional insecurity challenges, FGD and KIIs. The participants revealed that food-deficit mitigation programmes implemented by the government through DSD and United Nations' WFP were indicative of escalating challenges brought and aggravated by climate change impacts on smallholder water management. The farmers reported that rainfall was increasing under the questionnaire survey confirmed in the FGD that they were counting losses that resulted from Cyclone IDAI-induced floods. According to Liesdek (2021), cyclone IDAI-induced floods accounted for around 30% of damages and losses in agricultural outputs in Masvingo, Manicaland and parts of the Midlands province.

5.4 THE ROLES, CONTRIBUTIONS AND BARRIERS WITHIN LOCAL CLIMATE CHANGE AND WATER MANAGEMENT INSTITUTIONAL ARRANGEMENTS

Evidence from the study revealed that local climate and water management institutional arrangements were in various forms. These were constituted under the bureaucratic government system, local-level bureaucratic and democratically elected structures, the role of non-state actors, and community-based and water user institutions. This section discusses the institutional gaps and missing institutions and their roles in climate-compatible water management in dry lands.

The study findings are that most climate change and water institutions existed as bureaucratic government systems constituted by various policies, guidelines, acts and frameworks. The bureaucratic institutions fell neatly under specific and related government departments, ministries, parastatal, or bodies. Their influence depended on the administration level, with most having national, sub-national and local level representation. The DDF and AGRITEX extension services were noted as a well-established institutional arrangement from the national level down to local communities, with varying roles and responsibilities, depending on the influence level. Planning, policy coordination and monitoring roles were identified as central in national and sub-national level institutions.

In contrast, community engagement, infrastructure development, and operation and maintenance roles were associated with the district, local ward and village-level institutions.

Evidence from this study identified the presence of replica institutional arrangements within water governance. The district water and sanitation subcommittees (DWSSCs) and the provincial water and sanitation subcommittees (PWSSCs) were present. They offered multi-level planning and leadership for water and sanitation, as noted by Care International (2017) in the Chivi district and as a countrywide strategy (Adaptation Fund, 2020; Government of Zimbabwe, 2012b, 2015c). Operational efficiency depends on planning and resource mobilization at different levels. The need to ensure effective coordination mechanisms, regulation and policy enforcement was noted to have faced some impediments related to funding, political will, and outreach challenges.

The study findings further identified the local-level bureaucratic and democratically selected structures in the form of VIDCOs and WADCOs. The VIDCOs and WADCOs' roles in planning and executing water and other developmental activities at local villages and ward levels indicated an organized system where local water users and smallholder farmers affected by climate change participated in local-level planning, decision-making and direct implementation of their priority plans. As structures elected democratically and overseen by traditional leaders and elected Councillors (Table 2.3 and 2.4), the identification of committee members was found to have not considered any technical qualifications for the office bearers. Membership enrolment was again guided by the Traditional Leaders Act for VIDCOs (Government of Zimbabwe, 1998a) and the RDC Act for WADCOs (Government of Zimbabwe, 2002a), as explained in section 4.2.1. Besides being properly organized as important lower-level structures, overlaps within the WADCOs and VIDCOs were identified as areas that may require close monitoring.

Non-State Actors' role in climate change and water resources was found to be key in information services, awareness raising and funding provision. Various NGOs, CBOs, faith-based organizations, and private sector organizations were noted to have provided project funding and awareness and facilitated capacity building for local structures in managing water resources in climate-impacted communities of the Chiredzi and Zvishavane districts. Key areas identified for attention are funding challenges. These resulted in reduced coverage and affected the length of the project intervention period. The NGOs' complementary role in community development and humanitarian assistance was noted to be increasing, as revealed in the Zimbabwe Humanitarian Appeal (UNOCHA, 2019) and district profiles (Government of Zimbabwe & World Food Programme, 2017a, 2017b). According to UNOCHA (2019), the

Zimbabwean government 2019 declared a state of emergency during the 2019/2020 drought that affected 5.1 million people and required USD464 million, as detailed in the international appeal for humanitarian assistance. The increasing role of non-state actor organizations proved critical in community development, including water management in dry lands.

Evidence from the study revealed gaps and missing institutions that constrained the fulfilment of certain climate change and water infrastructure roles. The local level water user or Asset Management Committees (AMC) were found to be existing information of IMC, DTC, WPC and the VPM. However, study findings indicated that VPMs were overloaded and overwhelmed. These local-level institutions are mainly voluntary, untrained, resource-constrained and mostly the older men since most youths shun them for greener pastures. This may explain the high numbers of non-functional and collapsed water points (Figure 4.26 and Figure 4.25). The absence of an active private sector player in climate change and water management at the local level undermines the socio-economic viability of programmes and policies that require private sector backing. An example of Kenya was noted as a starting point where the private sector offered service maintenance for rural water supply (Villholth & Conti, 2019). The study identified gaps in local public media for awareness raising and lack of decentralized weather and climate services as key gaps that programs and policies may need to solve.

The future of local institutions was therefore poised for growth and strengthening due to the country's direction towards devolution. Accordingly, the government committed through the constitution, Section 264 (2) (a) ***"To give powers of local governance to the people and enhance their participation in the exercise of powers of the state and in making decisions affecting them"*** (Government of Zimbabwe, 2013a).

5.5 STRATEGIES FOR CLIMATE CHANGE COMPATIBLE WATER MANAGEMENT IN DRY AREAS

This study revealed that governance strategies, water conservation and replenishment strategies and risk management strategies provided cross-cutting opportunities for communities, climate and water actors to solve underlying leadership, resource mobilization, legal, coordination and resource mobilization gaps.

Governance was identified as an overarching strategy from which smallholder farmers and stakeholders might benefit. Governance can be defined as the "ability to make and enforce rules and to deliver services" (Fukuyama, 2013), and a wide range of social, political, economic and administrative mechanisms (Batchelor, 2009) are put in place as enablers. According to the study's case studies, climate change governance was identified as weak and not fully developed at the local level of climate vulnerability. However, water governance frameworks in Zimbabwe were developed and are in place. Rural communities of Chiredzi and Zvishavane indicated that various governance tools and mechanisms are in place, including community management approaches for common water sources. Both ILK/IKS and government-driven policies and frameworks provide governance water mechanisms. The Zimbabwe National Water Authority (ZINWA) was mandated as the sole regulator of surface and groundwater resources in Zimbabwe (Government of Zimbabwe, 2002c). However, the operations at ZINWA's catchment and sub-catchment council level indicated that their coverage in the local community required structural and budgetary support to reach the minimum levels. This may be why groundwater information is not being generated and available for monitoring and decision-making. The regulator is disconnected from the users. Lack of enforcement for certain water management standards was also found to be the main reason behind overuse and poor maintenance of community water sources and lack of funding (Bowora et al., 2016).

In this study, water conservation and replenishment were reported as instrumental in protecting and developing water sources for smallholder farmers in dry lands. Wetlands, deep wells, springs and boreholes were identified to have received community attention. The World Food Programme (2021) revealed that water harvesting is a key practice that improves water utilization and management in water-stressed communities. The seasonality in water supply in both Chiredzi and Zvishavane districts was identified as a key area that has resulted in water deficit for the rainfed communities. Using the WFP's seasonal livelihoods programming (SLP) (World Food Programme, 2021), key lessons may be drawn for managing water supply through a seasonal water management calendar. Evidence from the research revealed that groundwater and surface water resources were treated without integration as required and promoted by the IWRM and national policies. Winter et al. (1998) indicated the need to treat surface and groundwater as a single resource. This idea was further promoted by the IWRM (Anderson et al., 2009; Global Water Partnership, 2000; Government of Zimbabwe, 2012b; SADC-GMI, 2019). It was an interesting finding that water conservation and replenishment strategies might be scaled up to new sustainable levels when rainwater and surface water harvesting are considered under policies and practices that require attention.

The management of risk within smallholder water resources under the changing climate was reported as a key requirement for communities that sources their risk management strategies from government and humanitarian or development partners during times of need. The absence of tailor-made insurance for cushioning smallholder farmers was noted during a focus group discussion with the DRR committees in the Chiredzi district. The low coverage (Figure 4.27) in the early warning systems (EWS) due to remoteness and possibly because of centralized weather and climate information services were identified as areas that may increase the smallholder farmer's vulnerability to risks. They are not fully developed. Different initiatives were implemented around smallholder farmers' insurance and risk management in Zimbabwe, including the R4 and Africa Risk Capacity (World Food Programme, 2015; Arce, 2016), which were all donor-driven. Several other forms of risk management, including community-based internal Savings and Lending Schemes (ISALs), were widely promoted as social safety nets. The ISALs have a long winding history of modification and practices worldwide. Based on the Zimbabwean experience, ISALs performance was also based on seasonal and economic performance. Both macroeconomic and microeconomic environments heavily impact on them. Therefore, there is a need for ISALs to be graduated into sustainable institutions that, when capacitated, may provide rural financial inclusion and risk management.

5.6 INTRODUCING A "SYSTEMS BASED ADAPTIVE WATER MANAGEMENT FRAMEWORK"

After presenting empirical results and in-depth discussion on gaps, best strategies and the identified climate change related opportunities for water management in drylands, the study proposes a new framework that integrates IWRM and CCD frameworks with the context-specific needs of communities in dry lands. With a futuristic approach, the framework took into consideration the past and present experiences as well as practices to develop the model, a "Systems Based Resilient Water Management Framework" (Figure 5.1) that integrated four key areas; the hydrological services, seasonality, financial instruments, and institutional arrangements that are overarching pillars for themes within IWRM and CCD framework.

A systems approach enables interconnected and linked relationships to work, reinforcing each other (IPCC, 2022b). Smallholder water management in the changing climate system was identified to thrive better on the interdependence of political, socio-economic, and biological/ecological contexts. With targets around water availability, water use management, water resources governance and improved investments in the water sector, the framework aims to achieve resilient water for smallholder farming communities.

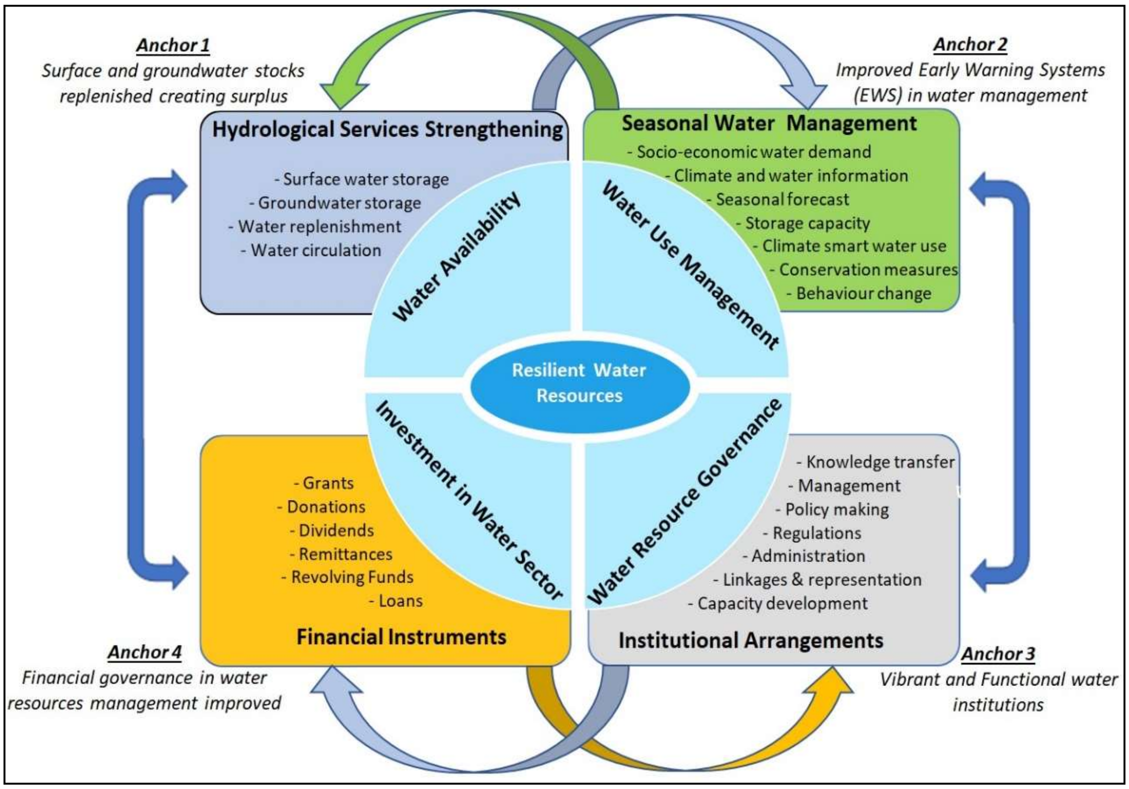

Figure 5.1 A systems based adaptive water management framework.
***Source**: Author, 2022*

A key area is **strengthening hydrological services** to enhance water availability by promoting surface and groundwater storage, replenishment, and circulation within the hydrological cycle. Practices that encourage surface and groundwater stock replenishment create a surplus that can cushion communities during droughts. The role played by hydrometeorological actors, including the CPU, MSD, and AGRITEX, was supported by Tamagnone et al. (2020). Ensuring the quality of climate and weather information was identified as a pillar for adaptation (Brausmann et al., 2021 & Meque et al., 2021).

Key interventions around demand management, climate and water information, seasonal forecasting and scenario planning, storage capacity enhancement, climate-smart water use and behaviour change have reinforcement effects for contributing to resilient water resources. **Seasonal Water Management** practices that provide context-specific water use management are anchored on improved EWS in water management. In Zimbabwe, seasonal rainfall averaging 657mm per year (FAO, 2019a), is received between November and March (Meteorological Services Department, 2018, 2020; ZIMSTAT, 2016b). The surface water produced internally in Zimbabwe was estimated to be 11.26 km^3, while groundwater accounted for six km^3 (FAO, 2019a). Based on the history of droughts in Zimbabwe (Frischen et al., 2020; Government of Zimbabwe, 2019b; Nangombe, 2015; SADRI, 2021; Welt Hunger Hilfe & Government of Zimbabwe, 2021) and low yielding status of groundwater aquifers (Davies & Burgess, 2014; Love et al., 2005; Macdonald & Edmunds, 2014; Nijsten et al., 2018), there is need for considering seasonality in water management for dry lands.

Financial Instruments were identified with a great need for strengthening to ensure an increase in water sector investments. Lack of financial inclusion for smallholder water management was noted as part of the reasons behind poor sectoral performance at the community level (Kativhu et al., 2018). The framework emphasizes establishing strong anchors for improved financial governance in water management. When the financial governance mechanism is functional, grants, donations, and dividends function better. Remittance, revolving funds and loans work better and produce results.

Achieving vibrant and functional water institutions is a huge step towards water resources governance. **Institutional arrangements** were identified as a critical area for improved water resources governance, planning and sectoral coordination mechanisms. Knowledge transfer, management functions, policy formulation and coordination, compliance, administrative roles, linkages and representations and capacity building are some institutional roles the framework promotes. A basket of institutions identified by the study required blending, with new and traditional institutions that had never worked together.

5.7 CONCLUSION

Different opportunities and challenges were discussed in the interest of smallholder water management in rainfall-marginal areas. An in-depth discussion on the strategies for climate-compatible water management was supported by the new "systems-based resilient water management framework", whose four pillars provide all-around anchors to sustain smallholder water management in the changing climatic, political and economic context. It is critical to note that any water management strategy should be implemented in a climate-smart manner that prevents maladaptation (Barnett & O’Neill, 2010). Promoting a low-carbon framework (The World Bank Group, 2020, 2021) and ecosystems-based adaptation (IPCC, 2022b) are key strategies that keep water management aligned with climate change ambitions.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

Key research conclusions and recommendations are provided in this chapter. The study's main aim was to investigate how smallholder farmers in dry lands adapt to climate change using climate-compatible water management strategies. Smallholder farmers in the southern dry lands of Zimbabwe were targeted because of their increased vulnerability to the impact of climate change and variability on water resources. The empirical evidence from the study and the detailed discussion of the findings were done in chapters four and five, respectively. This conclusions and recommendations chapter has three main sections, including the first (section 6.1), which is an introductory part. Section 6.2 presented conclusions on climate-compatible water resource management in dry lands. The overall recommendations are presented in section 6.3.

6.2 CONCLUSIONS

In line with the study's aim of assessing climate-compatible smallholder water management in drylands, the study concludes with opportunities, constraints, institutional arrangements, and climate-compatible water management strategies from climate change.

The research revealed that, despite the overshadowing effects of climate change-related constraints, water harvesting, funding and partnership, technology and knowledge transfer were identified as key opportunities that smallholder farming communities may derive benefits. The study participants from a questionnaire survey, KIIs and FGDs indicated an increase in the water harvesting opportunities introduced by extension services providers and non-governmental organizations under the climate-smart agriculture approaches. The study revealed that some practices promoted in response to climate change received programmes and policy support. The locally adapted conservation farming through reduced tillage, also known and promoted locally as "*Pfumvudza/Intwasa*" (Edwards et al., 2020), received support from the government, private sector, NGOs and the international development partners.

A basket of water harvesting practices was identified as a key opportunity brought by climate change to smallholder farmers in dry lands. The half-moon (*Zaï*) pits (Motis et al., 2013), infiltration pits, micro basins, water retention ditches and trenches were identified as key surface and infield water harvesting techniques. Roof catchment for rainwater harvesting was used as a collection mechanism for domestic water by farmers. Water harvesting activities were therefore identified as necessary adaptation pathways for a water secure and replenished dry land.

Funding partnerships, technology and knowledge transfer opportunities were identified as increasing compared to previous decades, partly as an answer to Zimbabwe's changing and highly variable climatic conditions. The increase in the number of boreholes drilled by donors and the release of adaptation funding earmarked for Zimbabwe were positive developments. Despite the fragmented nature, the smaller size of the funding schemes available and the high costs related to technology transfer, smallholder farmers realized benefits from solar-powered water pumping systems.

As demonstrated by many other studies, the research revealed that the magnitude, frequency, and unpredictability of weather and climatic events increased and resulted in catastrophic events that affected vulnerable communities like smallholder farmers in dry lands. When droughts occur, their intensity and impacts extend for more years than anticipated. The identified floods resulted in communities taking longer to recover due to disrupted services, economy and livelihoods.

The study identified challenges with decentralizing weather and climate information services value chains as key areas of attention. Regarding institutional arrangements, the study demonstrated the existence and importance of various institutions. Interestingly, the research revealed gaps and missing institutions whose roles are needed to fill the climate-compatible water management service providers' role. The absence of a strong private sector service provider player in rural water management indicated the gap in investment opportunities and operation and maintenance. Local public media gaps were identified in Chiredzi, where the smallholder farmers relied on Mozambican and South African radio reception as observed during data collection. The low coverage of the main broadcasting services was identified as a key aspect fuelling vulnerability among flood and drought-prone communities that is cut from the mainstream public media services, which provided weather and climate information services.

Several strategies were identified as key enablers for enhancing climate-compatible water management in dry lands. Governance strategies looked at how community power and management frameworks direct efforts towards water management in various locations. It was interesting to note that governance issues were aligned with political will and formal and informal frameworks that constrained water management in smallholder farming communities. Different legal frameworks, water institutions and several overlaps were identified as the reason behind the water sector's discordancy.

6.3 RECOMMENDATIONS

Several actions must be implemented to ensure water management is achieved despite the changing and highly variable climatic context. In light of the discussions presented in this study, recommendations have been put forward to ensure that climate-compatible smallholder water management in drylands may be achieved. The findings of the study suggested the following areas for recommendations.

6.3.1 SCALING UP WATER HARVESTING

The study's findings indicated that smallholder farmers and their stakeholders recommended scaling up water harvesting activities to balance the available water resources and their demands. Increasing the storage facilities for rainwater harvesting will enable smallholder farmers have enough water and reduce conflicts at community water points that were reported to increase during the peak dry season. Rainwater harvesting intervention proved sustainable and therefore calls for urgent action and inclusion as a policy and programme implementation priority.

6.3.2 SEASONALITY CHALLENGES IN WATER RESOURCES

Seasonal water management calendar development and adoption for use were recommended by NGOs/CBOs, extension services providers and lead farmers who pointed out the existence of a similar framework known as the seasonal livelihoods programme (SLP). The seasonal water management calendar, like the SLP, must assess the available resources, including water throughout the year and manage water resources in line with availability and needs at specific times.

6.3.3 CAPACITATING LOCAL INSTITUTIONS TO OFFER CLIMATE AND WATER SERVICES

The study recommended that local institutions positioned better to work with smallholder farmers must be capacitated to offer climate and water management services. The following institutions were identified and recommended for capacitation:

i. Due to the huge gap in local public media coverage, the study recommended strengthening community radio programmes initiated by the Ministry of Information, Publicity and Broadcasting Services. Chiredzi district launched ***Avuxeni FM*** during research data collection, which was viewed as a great opportunity for accelerating climate and weather information dissemination to Chiredzi communities that traditionally faced national broadcaster coverage challenges.

ii. The study recognized the existence and resilience of IKS/ILK in weather and climate information services. Without proper documentation of the practices, lack of standardization, supporting policy and institutional framework, IKS/ILK is under threat from sustainability. There is a need for integration of the IKS/ILK with the scientific hydrometeorological observations to enhance weather and climate product co-creation, community preparedness and sustainability of the services.

6.3.4 REVISITING OPERATION AND MAINTENANCE FRAMEWORK FOR WATER INFRASTRUCTURE

The study's findings revealed that a significant proportion of water points were non-functional due to poor operation and maintenance, with the few remaining VPM being overloaded and lacking maintenance equipment and mobility. There is a need for the rural water supply sector to consider revisiting the operation and maintenance framework by developing a water-related social enterprise that generates income and sustains service provision.

6.3.5 IMPROVING SURFACE AND GROUNDWATER STORAGE AND YIELD MONITORING

A key challenge in water management is the absence of quality data and information. The potential of aquifers in various locations is unknown, the same applies to the recharge capacity. The study recommends that every water point be capacitated to generate point source information and keep the related records as a key step in planning and management of water.

6.3.6 RISK MANAGEMENT APPROACH IN CLIMATE CHANGE AND WATER MANAGEMENT

Although some challenges were noted in the implementing weather-indexed insurance (WII) as supported by (Arce, 2016), the study recommends that WII and other water infrastructure risk management strategies be modified and scaled up to suit smallholder farmers' needs.

6.3.7 ECOSYSTEMS BASED ADAPTATION

The promotion of a low-carbon water management framework and prevention of maladaptation should be implemented, considering the community's heavy reliance on fragile wetlands and invisible groundwater.

6.3.8 STRENGTHENING WEATHER AND CLIMATE INFORMATION SERVICES

With a focus on smallholder farmers in dry lands, hydrometeorological information was noted as a key determinant in climate change and water vulnerability. The study, therefore, recommends capacitating hydrometeorological service providers and integrating ILK/IKS with scientific knowledge. This will improve weather and climate information services to dry land communities.

6.3.9 Policy and practices need to be developed to ensure there is increased coverage and decentralized hydrometeorological and financial service providers. by the number of weather stations coupled with the insufficient coverage of public information dissemination and reception in remote areas.

6.3.10 Developing and implementing Standard Operating Procedures (SOPs) and enforcing them into a community of practice is recommended for all climate-compatible water management activities. This ensures developments comply with a carbon-free economy whose decisions and programmes may be safe from maladaptation practices.

6.3.11 Financial Mechanisms need to be developed and scaled up to assist rural communities that are currently marginalised by the market.

6.3.12 Further Research is recommended in the following areas;

i. Groundwater use and vulnerability across different catchments and adaptation strategies.
ii. Strategies for adapting governance systems to cope with changing stock in resources base and climate risk.
iii. Climate financial mechanisms beneficial to smallholder communities in rainfall marginal areas.

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ANNEXURES

Annexure A: Ethical Clearance Certificate

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Manyakaidze

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H20/08/18**
PROJECT TITLE	Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe
INVESTIGATOR(S)	Mr P Manyakaidze
SCHOOL/DEPARTMENT	Geography, Archaeology and Environment/
DATE CONSIDERED	21 August 2020
DECISION OF THE COMMITTEE	Approved Risk Level: Minimal
EXPIRY DATE	15 September 2023

DATE 16 September 2020 **CHAIRPERSON** ______________________
(Professor J Knight)

cc: Supervisor : Professor M Simatele

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

______________________ 16 / 09 / 2020
Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Annexure B1: Information sheet for Community-Based Organizations or NGO officials

FACULTY OF HUMANITIES

SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

INFORMATION SHEET – COMMUNITY BASED ORGANIZATION OR LOCAL NGO OFFICIAL

Good Day,

My name is Pascal Manyakaidze and I am a PhD student in Geography at the University of the Witwatersrand, Johannesburg. As part of my studies, I have to undertake a research project, and my research is titled **"*Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe*"** I am conducting my study under the supervision of Prof. Mulala Simatele. The aim of this research project is to investigate how smallholder farmers adapt to climate change using climate change compatible water resources management. As part of this project, I would like to invite you to take part in a key informant interview. This activity will involve answering a set of questions in line with your role and will take around 40 minutes.

With your permission; I would also like to record the interview using a digital device. I would also kindly request for your permission to take photographs that will be used solely for this research purpose. If permitted, photographs will be taken when there is a case study, best practice or significant observation where photographs can aid in the reporting. Photographs taken will not intrude privacy, personal identification, sensitive or vulnerable contexts and will be used without manipulation.

As a national requirement and in line with permission letters, I will kindly request that we observe all the COVID-19 regulations. I will kindly request to provide materials for hand sanitization and surgical face masks you do not have these materials. May I also request that we keep at least two metres distance from each other and avoid exchange of any papers, ball pens, phones and other devices to prevent any chances of transmission of the virus.

Your participation in this research is voluntary and there will be no personal costs to you if you participate in this project, you will not receive any direct benefits from participation but there are no disadvantages or penalties if you do not choose to participate or if you withdraw from the study. You may withdraw at any time or not answer any question if you do not want to. Since I will be conducting the interviews, you will not remain anonymous to me although in the reports your information will be completely confidential and anonymous as I will not be asking and use your name or any identification information. The information you give to me will be held securely and not disclosed to anyone else. I will be using a pseudonym to represent your participation in my final research report for confidentiality and anonymity reasons. If you experience any distress or discomfort at any point in this process, we will stop the interview or resume another time.

If you have any questions during or afterwards about this research, feel free to contact me or my supervisor on the details below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you. The research data collected will be stored in locked trunk and will be kept for 7 years. With your permission the data collected from this research project may be used by other researchers (optional). If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0)11 717 1408, email hrecnon-medical@wits.ac.za .

Yours sincerely,

Pascal Manyakaidze – PhD Researcher

Phone: +263772582211; **Email**: 985959@students.wits.ac.za

Prof. Mulala Simatele – Supervisor

Phone: +27117176602 (office), +27833836884 (mobile); **Email**: Mulala.Simatele@wits.ac.za

Annexure B2: Information sheet for Community Based Water Management Structures

FACULTY OF HUMANITIES

SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

INFORMATION SHEET – COMMUNITY BASED WATER MANAGEMENT STRUCTURES

Good Day,

My name is Pascal Manyakaidze and I am a PhD student in Geography at the University of the Witwatersrand, Johannesburg. As part of my studies, I have to undertake a research project, and my research is titled **"*Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe*"** I am conducting my study under the supervision of Prof. Mulala Simatele. The aim of this research project is to investigate how smallholder farmers adapt to climate change using climate change compatible water resources management. As part of this project, I would like to invite you to take part in focus group discussion. This activity will involve interactive discussions about a subject topic presented by the researcher and will take around 60 minutes.

With your permission; I would also like to record the interview using a digital device. I would also kindly request for your permission to take photographs that will be used solely for this research purpose. If permitted, photographs will be taken when there is a case study, best practice or significant observation where photographs can aid in the reporting. Photographs taken will not intrude privacy, personal identification, sensitive or vulnerable contexts and will be used without manipulation.

As a national requirement and in line with permission letters, I will kindly request that we observe all the COVID-19 regulations. I will kindly request to provide materials for hand sanitization and surgical face masks you do not have these materials. May I also request that we keep at least two metres distance from each other and avoid exchange of any papers, ball pens, phones and other devices to prevent any chances of transmission of the virus.

Your participation in this research is voluntary and there will be no personal costs to you if you participate in this project, you will not receive any direct benefits from participation but there are no disadvantages or penalties if you do not choose to participate or if you withdraw from the study. You may withdraw at any time or not answer any question if you do not want to. Due to the nature of the focus group discussion and because I will be facilitating it, the discussed information will not be completely confidential and anonymous due to the interactive process. However your participation will remain confidential and anonymous in the reports since I will not use your name or any identification information. The information you give to me will be held securely and not disclosed to anyone else. I will be using a pseudonym to represent your participation in my final research report. If you experience any distress or discomfort at any point in this process, we will stop the interview or resume another time.

If you have any questions during or afterwards about this research, feel free to contact me or my supervisor on the details below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you. The data collected from this research project will be stored in locked trunk and will be kept for 7 years. With your permission the data collected from this research project may be used by other researchers. If you have any concerns regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0)11 717 1408, email hrecnon-medical@wits.ac.za .

Yours sincerely,

Pascal Manyakaidze – PhD Researcher

Phone: +263772582211; **Email**: 985959@students.wits.ac.za

Prof. Mulala Simatele – Supervisor

Phone: +27117176602 (office), +27833836884 (mobile); **Email**: Mulala.Simatele@wits.ac.za

Annexure B3: Information sheet for government or local authority official

FACULTY OF HUMANITIES

SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

INFORMATION SHEET – GOVERNMENT AND LOCAL AUTHORITY OFFICIAL

Good Day,

My name is Pascal Manyakaidze and I am a PhD student in Geography at the University of the Witwatersrand, Johannesburg. As part of my studies, I have to undertake a research project, and my research is titled **"*Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe*"** I am conducting my study under the supervision of Prof. Mulala Simatele. The aim of this research project is to investigate how smallholder farmers adapt to climate change using climate change compatible water resources management. As part of this project, I would like to invite you to take part in a key informant interview. This activity will involve answering a set of questions in line with your role and will take around 40 minutes.

With your permission; I would also like to record the interview using a digital device. I would also kindly request for your permission to take photographs that will be used solely for this research purpose. If permitted, photographs will be taken when there is a case study, best practice or significant observation where photographs can aid in the reporting. Photographs taken will not intrude privacy, personal identification, sensitive or vulnerable contexts and will be used without manipulation.

As a national requirement and in line with permission letters, I will kindly request that we observe all the COVID-19 regulations. I will kindly request to provide materials for hand sanitization and surgical face masks you do not have these materials. May I also request that we keep at least two metres distance from each other and avoid exchange of any papers, ball pens, phones and other devices to prevent any chances of transmission of the virus.

Your participation in this research is voluntary and there will be no personal costs to you if you participate in this project, you will not receive any direct benefits from participation but there are no disadvantages or penalties if you do not choose to participate or if you withdraw from the study. You may withdraw at any time or not answer any question if you do not want to. Since I will be conducting the interviews, you will not remain anonymous to me although in the reports your information will be completely confidential and anonymous as I will not be asking and use your name or any identification information. The information you give to me will be held securely and not disclosed to anyone else. I will be using a pseudonym to represent your participation in my final research report for confidentiality and anonymity reasons. If you experience any distress or discomfort at any point in this process, we will stop the interview or resume another time.

If you have any questions during or afterwards about this research, feel free to contact me or my supervisor on the details below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you. The research data collected will be stored in locked trunk and will be kept for 7 years. With your permission the data collected from this research project may be used by other researchers (optional). If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0)11 717 1408, email hrecnon-medical@wits.ac.za .

Yours sincerely,

Pascal Manyakaidze – PhD Researcher
Phone: +263772582211; **Email**: 985959@students.wits.ac.za

Prof. Mulala Simatele – Supervisor
Phone: +27117176602 (office), +27833836884 (mobile); **Email**: Mulala.Simatele@wits.ac.za

Annexure B4: Information sheet for local community leaders

FACULTY OF HUMANITIES

SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

INFORMATION SHEET – LOCAL COMMUNITY LEADER

Good Day,

My name is Pascal Manyakaidze and I am a PhD student in Geography at the University of the Witwatersrand, Johannesburg. As part of my studies, I have to undertake a research project, and my research is titled **"*Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe*"** I am conducting my study under the supervision of Prof. Mulala Simatele. The aim of this research project is to investigate how smallholder farmers adapt to climate change using climate change compatible water resources management. As part of this project, I would like to invite you to take part in a key informant interview. This activity will involve answering a set of questions in line with your role and will take around 40 minutes.

With your permission; I would also like to record the interview using a digital device. I would also kindly request for your permission to take photographs that will be used solely for this research purpose. If permitted, photographs will be taken when there is a case study, best practice or significant observation where photographs can aid in the reporting. Photographs taken will not intrude privacy, personal identification, sensitive or vulnerable contexts and will be used without manipulation.

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If you have any questions during or afterwards about this research, feel free to contact me or my supervisor on the details below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you. The research data collected will be stored in locked trunk and will be kept for 7 years. With your permission the data collected from this research project may be used by other researchers (optional). If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0)11 717 1408, email hrecnon-medical@wits.ac.za .

Yours sincerely,

Pascal Manyakaidze – PhD Researcher

Phone: +263772582211; **Email**: 985959@students.wits.ac.za

Prof. Mulala Simatele – Supervisor

Phone: +27117176602 (office), +27833836884 (mobile); **Email**: Mulala.Simatele@wits.ac.za

Annexure B5: Information sheet for local extension services providers

FACULTY OF HUMANITIES

SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

INFORMATION SHEET – LOCAL EXTENSION SERVICES PROVIDER

Good Day,

My name is Pascal Manyakaidze and I am a PhD student in Geography at the University of the Witwatersrand, Johannesburg. As part of my studies, I have to undertake a research project, and my research is titled **"*Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe*"** I am conducting my study under the supervision of Prof. Mulala Simatele. The aim of this research project is to investigate how smallholder farmers adapt to climate change using climate change compatible water resources management. As part of this project, I would like to invite you to take part in a key informant interview. This activity will involve answering a set of questions in line with your role and will take around 40 minutes.

With your permission; I would also like to record the interview using a digital device. I would also kindly request for your permission to take photographs that will be used solely for this research purpose. If permitted, photographs will be taken when there is a case study, best practice or significant observation where photographs can aid in the reporting. Photographs taken will not intrude privacy, personal identification, sensitive or vulnerable contexts and will be used without manipulation.

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Your participation in this research is voluntary and there will be no personal costs to you if you participate in this project, you will not receive any direct benefits from participation but there are no disadvantages or penalties if you do not choose to participate or if you withdraw from the study. You may withdraw at any time or not answer any question if you do not want to. Since I will be conducting the interviews, you will not remain anonymous to me although in the reports your information will be completely confidential and anonymous as I will not be asking and use your name or any identification information. The information you give to me will be held securely and not disclosed to anyone else. I will be using a pseudonym to represent your participation in my final research report for confidentiality and anonymity reasons. If you experience any distress or discomfort at any point in this process, we will stop the interview or resume another time.

If you have any questions during or afterwards about this research, feel free to contact me or my supervisor on the details below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you. The research data collected will be stored in locked trunk and will be kept for 7 years. With your permission the data collected from this research project may be used by other researchers (optional). If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0)11 717 1408, email hrecnon-medical@wits.ac.za .

Yours sincerely,

Pascal Manyakaidze – PhD Researcher
Phone: +263772582211; **Email**: 985959@students.wits.ac.za

Prof. Mulala Simatele – Supervisor
Phone: +27117176602 (office), +27833836884 (mobile); **Email**: Mulala.Simatele@wits.ac.za

Annexure B6: Information sheet for smallholder farmers

FACULTY OF HUMANITIES

SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

INFORMATION SHEET – SMALLHOLDER FARMER

Good Day,

My name is Pascal Manyakaidze and I am a PhD student in Geography at the University of the Witwatersrand, Johannesburg. As part of my studies, I have to undertake a research project, and my research is titled **"*Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe*"** I am conducting my study under the supervision of Prof. Mulala Simatele. The aim of this research project is to investigate how smallholder farmers adapt to climate change using climate change compatible water resources management. As part of this project, I would like to invite you to take part in answering the questionnaire. This activity will involve answering a set of questions in line with your role and will take around 35 minutes.

With your permission; I would also like to record the interview using a digital device. I would also kindly request for your permission to take photographs that will be used solely for this research purpose. If permitted, photographs will be taken when there is a case study, best practice or significant observation where photographs can aid in the reporting. Photographs taken will not intrude privacy, personal identification, sensitive or vulnerable contexts and will be used without manipulation.

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If you have any questions during or afterwards about this research, feel free to contact me or my supervisor on the details below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you. The research data collected will be stored in locked trunk and will be kept for 7 years. With your permission the data collected from this research project may be used by other researchers (optional). If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0)11 717 1408, email hrecnon-medical@wits.ac.za .

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Phone: +263772582211; **Email**: 985959@students.wits.ac.za

Prof. Mulala Simatele – Supervisor

Phone: +27117176602 (office), +27833836884 (mobile); **Email**: Mulala.Simatele@wits.ac.za

Annexure C1: Consent form for community-based organization or local NGO

FACULTY OF HUMANITIES
SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

CONSENT FORM – COMMUNITY BASED ORGANIZATION (CBO) OR LOCAL NGO

Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe

Pascal Manyakaidze (Student Number 985959)

I, ____, hereby agree to participate in this research project.

(Please circle the relevant options below)

The research has been explained to me and I understand what my participation is voluntary and do not accrue any benefits or disadvantages.	YES	NO
I understand that I may refuse to answer any particular question, withdraw from participation, and refuse voice recording or taking of photographs from the research if I wish without any negative consequences.	YES	NO
I understand that by agreeing to participate, I may not remain anonymous to the researcher who will conduct the interviews.	YES	NO
I expect that my responses will be kept confidential and anonymous in resulting report.	YES	NO
I agree that the information I provide may be used anonymously after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained.	YES	NO
I agree to the researcher's request for observing the COVID-19 regulations throughout the research interview processes.	YES	NO

Name of Participant : ___________________________________
Date of Consent : ___________________________________
Signature : ___________________________________

As a PhD researcher, I agree to be bound by the conditions mentioned and set in this consent form as well as the provisions set in the University of the Witwatersrand's Standard Operating Procedures of the Human Research Ethics Committee (Non Medical).

Name of PhD Researcher **:** Pascal Manyakaidze (Student Number 985959)
Date of Consent : ______________________________________
Signature : ______________________________________

Annexure C2: Consent form for community-based water management structure

FACULTY OF HUMANITIES
SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

CONSENT FORM – COMMUNITY BASED WATER MANAGEMENT STRUCTURE REPRESENTATIVE

Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe

Pascal Manyakaidze (Student Number 985959)

I, ____________________________________, hereby agree to participate in this research project.

(Please circle the relevant options below)

The research has been explained to me and I understand what my participation is voluntary and do not accrue any benefits or disadvantages.	YES	NO
I understand that I may refuse to answer any particular question, withdraw from participation, and refuse voice recording or taking of photographs from the research if I wish without any negative consequences.	YES	NO
I understand that by agreeing to participate, I may not remain anonymous to the researcher who will conduct the interviews.	YES	NO
I expect that my responses will be kept confidential and anonymous in resulting report.	YES	NO
I agree that the information I provide may be used anonymously after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained.	YES	NO
I agree to the researcher's request for observing the COVID-19 regulations throughout the research interview processes.	YES	NO

Name of Participant : ____________________________________
Date of Consent : ____________________________________
Signature : ____________________________________

As a PhD researcher, I agree to be bound by the conditions mentioned and set in this consent form as well as the provisions set in the University of the Witwatersrand's Standard Operating Procedures of the Human Research Ethics Committee (Non Medical).

Name of PhD Researcher : Pascal Manyakaidze (Student Number 985959)
Date of Consent : ______________________________________
Signature : ______________________________________

Annexure C3: Consent form for government and local authority official

FACULTY OF HUMANITIES
SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

CONSENT FORM – GOVERNMENT AND LOCAL AUTHORITY OFFICIAL

Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe

Pascal Manyakaidze (Student Number 985959)

I, ____, hereby agree to participate in this research project.

(Please circle the relevant options below)

The research has been explained to me and I understand what my participation is voluntary and do not accrue any benefits or disadvantages.	YES	NO
I understand that I may refuse to answer any particular question, withdraw from participation, and refuse voice recording or taking of photographs from the research if I wish without any negative consequences.	YES	NO
I understand that by agreeing to participate, I may not remain anonymous to the researcher who will conduct the interviews.	YES	NO
I expect that my responses will be kept confidential and anonymous in resulting report.	YES	NO
I agree that the information I provide may be used anonymously after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained.	YES	NO
I agree to the researcher's request for observing the COVID-19 regulations throughout the research interview processes.	YES	NO

Name of Participant : ___________________________________
Date of Consent : ___________________________________
Signature : ___________________________________

As a PhD researcher, I agree to be bound by the conditions mentioned and set in this consent form as well as the provisions set in the University of the Witwatersrand's Standard Operating Procedures of the Human Research Ethics Committee (Non Medical).

Name of PhD Researcher **:** Pascal Manyakaidze (Student Number 985959)
Date of Consent : ______________________________________
Signature : ______________________________________

Annexure C4: Consent form for local community leader

FACULTY OF HUMANITIES
SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

CONSENT FORM – LOCAL COMMUNITY LEADER

Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe

Pascal Manyakaidze (Student Number 985959)

I, ____, hereby agree to participate in this research project.

(Please circle the relevant options below)

The research has been explained to me and I understand what my participation is voluntary and do not accrue any benefits or disadvantages.	YES	NO
I understand that I may refuse to answer any particular question, withdraw from participation, and refuse voice recording or taking of photographs from the research if I wish without any negative consequences.	YES	NO
I understand that by agreeing to participate, I may not remain anonymous to the researcher who will conduct the interviews.	YES	NO
I expect that my responses will be kept confidential and anonymous in resulting report.	YES	NO
I agree that the information I provide may be used anonymously after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained.	YES	NO
I agree to the researcher's request for observing the COVID-19 regulations throughout the research interview processes.	YES	NO

Name of Participant : ____________________________________
Date of Consent : ____________________________________
Signature : ____________________________________

As a PhD researcher, I agree to be bound by the conditions mentioned and set in this consent form as well as the provisions set in the University of the Witwatersrand's Standard Operating Procedures of the Human Research Ethics Committee (Non Medical).

Name of PhD Researcher : Pascal Manyakaidze (Student Number 985959)
Date of Consent : ______________________________________
Signature : ______________________________________

Annexure C5: Consent form for local extension service provider

FACULTY OF HUMANITIES
SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

CONSENT FORM – LOCAL EXTENSION SERVICE PROVIDER

Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe

Pascal Manyakaidze (Student Number 985959)

I, ____, hereby agree to participate in this research project.

(Please circle the relevant options below)

The research has been explained to me and I understand what my participation is voluntary and do not accrue any benefits or disadvantages.	YES	NO
I understand that I may refuse to answer any particular question, withdraw from participation, and refuse voice recording or taking of photographs from the research if I wish without any negative consequences.	YES	NO
I understand that by agreeing to participate, I may not remain anonymous to the researcher who will conduct the interviews.	YES	NO
I expect that my responses will be kept confidential and anonymous in resulting report.	YES	NO
I agree that the information I provide may be used anonymously after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained.	YES	NO
I agree to the researcher's request for observing the COVID-19 regulations throughout the research interview processes.	YES	NO

Name of Participant : ___________________________________
Date of Consent : ___________________________________
Signature : ___________________________________

As a PhD researcher, I agree to be bound by the conditions mentioned and set in this consent form as well as the provisions set in the University of the Witwatersrand's Standard Operating Procedures of the Human Research Ethics Committee (Non Medical).

Name of PhD Researcher **:** Pascal Manyakaidze (Student Number 985959)
Date of Consent : ___________________________________
Signature : ___________________________________

Annexure C6: Consent form for smallholder farmer

FACULTY OF HUMANITIES
SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

CONSENT FORM – SMALLHOLDER FARMER

Assessing climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe

Pascal Manyakaidze (Student Number 985959)

I, ____, hereby agree to participate in this research project.

(Please circle the relevant options below)

The research has been explained to me and I understand what my participation is voluntary and do not accrue any benefits or disadvantages.	YES	NO
I understand that I may refuse to answer any particular question, withdraw from participation, and refuse voice recording or taking of photographs from the research if I wish without any negative consequences.	YES	NO
I understand that by agreeing to participate, I may not remain anonymous to the researcher who will conduct the interviews.	YES	NO
I expect that my responses will be kept confidential and anonymous in resulting report.	YES	NO
I agree that the information I provide may be used anonymously after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained.	YES	NO
I agree to the researcher's request for observing the COVID-19 regulations throughout the research interview processes.	YES	NO

Name of Participant : ___________________________________
Date of Consent : ___________________________________
Signature : ___________________________________

As a PhD researcher, I agree to be bound by the conditions mentioned and set in this consent form as well as the provisions set in the University of the Witwatersrand's Standard Operating Procedures of the Human Research Ethics Committee (Non Medical).

Name of PhD Researcher : Pascal Manyakaidze (Student Number 985959)
Date of Consent : ______________________________________
Signature : ______________________________________

Annexure D: Questionnaire for individual smallholder farmer

FACULTY OF HUMANITIES
SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

Questionnaire: Individual Smallholder Farmer

This research assesses climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe. It aims to identifying opportunities, constraints and the role of local institutions in climate compatible smallholder water management in the dry lands. Establishing the strategies that can be adopted to improve climate compatible smallholder water management is key in this research. The researcher selected you to participate in the study because you are part of smallholder farmers in the targeted community. I will be very grateful if you agree to participate in this study by completing this questionnaire with my assistance and participating in any follow up interviews. Your responses will be kept confidential and anonymous. No personal identification information, names and religion or any personal sensitive information will be requested or captured. I therefore kindly request you to complete the consent form to indicate that you have agreed to participate in this research.

Administrative Section

<table>
<tr><td colspan="3">Kindly fill the following section</td></tr>
<tr><td colspan="3">Household Number : ____________________ Village: ____

Ward: __________________________________ District : ____</td></tr>
<tr><td colspan="3">Kindly indicate your response by ticking the appropriate selection.</td></tr>
<tr><td>Gender
:
01 Male [ ]
02 Female [ ]</td><td>Age range :
01 18 – 35 [ ]
02 36 – 45 [ ]
03 46 – 64 [ ]
04 65 + [ ]</td><td>Length of stay in the community
01 less than 5 years [ ]
02 5 to 15 years [ ]
03 16 to 30 years [ ]
04 over 30 years [ ]</td></tr>
</table>

Land Tenure			**Comment on land tenure:**
01	Freehold ownership	[ ]	
02	Occupancy right to land in communal areas	[ ]	
03	A1 Old Resettlement Village Schemes	[ ]	
04	A1 New Resettlement Village Schemes	[ ]	
05	A1 New Resettlement Self contained plots	[ ]	
06	A2 New Resettlement Schemes	[ ]	
07	Others (Specify)________________________________	[ ]	

Section A

Kindly answer the following question by filling, ticking the selected box and giving explanation where possible.

1. Have you ever heard of climate change?

   1. Yes [ ]
   2. No [ ]
   3. Not Sure [ ]

   Comment:

2. May you kindly identify your key sources of water?

Water Use	Sources	Ownership	Comment
Domestic – drinking			
Domestic – cleaning			
Agriculture – irrigation			
Agriculture – livestock			
Other …			
Other ….			

3. In your opinion, has climate change affected smallholder water resources? 1. Yes [ ] 2. No [ ]

	3. Don't know [ ] Explain your answer:
4.	How would you rate the vulnerability of smallholder farmers' water resources climate change? (Tick a box)

Increasing	**Decreasing**	**No change**	**Not sure**

Explain your selection:

5.	In what ways do climate change affect smallholder farming water resources and related activities?

Effects	**Comment**

6.	In your views, what can be the climate compatible opportunities for SHF water management? a) Male: b) Female:
7.	How important is climate compatible smallholder farmers' water resources management to you?

Very Important	**Important**	**Not very Important**	**Not important at all**

	Explain your answer:
8.	If you may recall, how was your area's rainfall over the past 30 years? Tick appropriate section and comment.

Period (Years)	Very High	High	Low	Very Low	Varying	Comment
31years + (1989 backwards)						
21-30 years (1990 – 1999)						
11-20 years (2000 – 2009)						
6-10years (2010 – 2014)						
1-5years (2015 – present)						

9. If you may recall, how was your area's temperature over the past 30 years? Tick appropriate.

Period (Years)	Very High	High	Low	Very Low	Varying	Comment
31years + (1989 backwards)						
21-30 years (1990 – 1999)						
11-20 years (2000 – 2009)						
6-10years (2010 – 2014)						
1-5years (2015 – present)						

10. If you may recall, how was your area's surface water sources yields over the past 30 years? Tick appropriate.

Period (Years)	Very High	High	Low	Very Low	Varying	Comment
31years + (1989 backwards)						
21-30 years (1990 – 1999)						
11-20 years (2000 – 2009)						
6-10years (2010 – 2014)						
1-5years (2015 – present)						

11. If you may recall, how was your area's ground water sources yields over the past 30 years? Tick appropriate

Period (Years)	Very High	High	Low	Very Low	Varying	Comment
31years + (1989 backwards)						
21-30 years (1990 – 1999)						
11-20 years (2000 – 2009)						
6-10years (2010 – 2014)						
1-5years (2015 – present)						

12. What is your experience pertaining to the following areas in relation to climate change on smallholder water?

Areas affected	Impact				Comment
	No Change	Increased	Decreased	Varying	
Rainfall distribution					
Total annual rainfall (mm)					
Temperature (°C)					
Length of growing season					
Surface water availability					
Ground water availability					
Crop pests					
Animal diseases					
Natural shocks and hazards					
Other? ____________________					
Other? ____________________					

13 What are the existing capacities of smallholder farmers in dealing with climate compatible water resources management?

a) Capacities for Men

Capacity	
Land tenure	

Skills	
Infrastructure	
Technology	
Funding mechanisms	
Indigenous Knowledge Systems (IKS)	
Policies	
Institutional linkages	
Other:	
Other:	

b) Capacities for Women

Capacity	
Land tenure	
Skills	
Infrastructure	
Technology	
Funding mechanisms	
Indigenous Knowledge Systems (IKS)	
Policies	
Institutional linkages	
Other:	
Other:	

Section B

Kindly answer the following question by filling, ticking the selected box and giving explanation where possible.

14. Which are the existing institutions / individuals who have key roles and capacity in climate compatible water resources management?

Institutions / Individuals	**Roles and Capacity**

15. In your opinion, who else should be part of climate compatible water management activities in your community?

Who	**Key roles / Comment**

16. From your list, who do you think should take the main responsibilities in climate compatible water resources management?

Who	**Comment**

17. Climate compatible water resources management service providers

Services	**Providers**	**Delivery Mechanism**	**Any adjustment**
Awareness and Education			
Conservation works			
Weather & climate Information			
IKS forecasts and practices			
Funding			
Equipment and Mechanization			
Energy supply			
Technology			
Research			
Policies and Legislative			
Communication			

Disaster Risk Management			
Market linkages			
Skills			
Extensions services			
Organising Farmers			
Innovations			
Transportation			
Legal representation			
Surface water information			
Ground water information			
Other? _______________			
Other? _______________			

Section C

Kindly answer the following question by filling, ticking the selected box and giving explanation where possible.

18. Which climate compatible water management strategies do you know that are used in your community?

19. Can you mention cases where these strategies were implemented and what was their performance?

Cases and performance	Reasons for performance

20. What gaps needs to be addressed within the current strategies to support climate compatible water management?

21. What are the key lessons and best practices that can be adopted, improved and replicated in a different context?

22.	What form of support do you require in order to address climate change impacts on smallholder water resources?

Internal support (from within the community)	**Comment**
External support (from outside your community)	**Comment**

If you may have anything to add about this research or any comments please note the in this section.

END

Annexure E1: Focus Group Discussion guide for smallholder farmers

FACULTY OF HUMANITIES

SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

Focus Group Discussion Guide

Smallholder Farmers

*This research assesses climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe. It aims to identifying opportunities, constraints, and the role of local institutions in climate compatible smallholder water management in the dry lands. Establishing the strategies that can be adopted to improve climate compatible smallholder water management is key in this research. The researcher selected you to participate in the study because you are a smallholder farmer in the targeted community. I will be very grateful if you agree to participate in this study's focus group discussion. No personal identification information, names and religion or any personal sensitive information will be requested or captured. I therefore kindly request you to complete the consent form to indicate that you have agreed to participate in this research.

1. Are you in a position to share your experience about climate change and smallholder water management in your community?
2. Can we discuss about the climate change and water risks affecting your farming water resources?
3. Can we discuss about constraints brought by climate change to smallholder water resources management in dry areas?
4. Do you think smallholder farming women and men are affected the same by climate change?
5. Can we discuss about different capacities that men and women smallholder farmers have to implement climate compatible water resources management?
6. Are you in a position to discuss about constraints by men and women smallholder farmers in water resources management?
7. Can we discuss anything that you need to **start, continue** or **stop doing** to ensure climate compatible water resources management in your community?
8. Are you in a position to discuss about what you think other stakeholders need to **start, continue** or **stop** doing to ensure climate compatible smallholder water management?

9. Do you have any lessons learned from climate change water resources management for smallholder farmers that can be replicated to a wider context?
10. Do you suggest any modification to any intervention by any actor that can result in climate compatible smallholder water management?
11. Do you have any additional information, question or clarification about this research?

Annexure E2: Focus Group Discussion guide for smallholder farmers

FACULTY OF HUMANITIES

SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

Focus Group Discussion Guide

Community Based Water Management Structures

This research assesses climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe. It aims to identifying opportunities, constraints and the role of local institutions in climate compatible smallholder water management in the dry lands. Establishing the strategies that can be adopted to improve climate compatible smallholder water management is key in this research. The researcher selected you to participate in the study because you are a member of community based water management structures assisting smallholder farmers in the targeted community. I will be very grateful if you agree to participate in this study's focus group discussion. Your responses will be kept confidential and anonymous in the research report. No personal identification information, names and religion or any personal sensitive information will be requested or captured. I therefore kindly request you to complete the consent form to indicate that you have agreed to participate in this research.

12. Are you in a position to share your experience with climate change and smallholder water management in your community?
13. Can we discuss about the climate change risks affecting smallholder water resources?
14. Can we discuss about constraints brought by climate change to smallholder water resources management in dry areas?
15. Do you think smallholder farming women and men are affected the same by climate change?
16. Do you have bye-laws related to climate change and water that you enforce?
17. What limitations do you encounter in implementing your work in water resources at the community level?

18. Can we discuss anything you may need to **start, continue** or **stop doing** to ensure climate change compatible water resources management in your community?
19. Are you in a position to discuss about what you think other stakeholders need to **start, continue** or **stop** doing to ensure climate compatible smallholder water management?
20. Are you in a position to share your views about different seasonal water management strategies needed to support smallholder farmers?
21. Do you have any lessons learned from climate change water resources management for smallholder farmers that can be replicated to a wider context?
22. Can we discuss about your capacity and need for you to effectively manage smallholder water resources?
23. Do you suggest any modification to any different intervention by any actor that can result in effective climate compatible smallholder water management?
24. Do you have any additional information, question or clarification about this research?

Annexure F1: Key informant interview guide for government and local authority officials

FACULTY OF HUMANITIES

SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

Key Informant Interview Guide

Government and Local Authority Officials

This research assesses climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe. It aims to identifying opportunities, constraints and the role of local institutions in climate compatible smallholder water management in the dry lands. Establishing the strategies that can be adopted to improve climate compatible smallholder water management is key in this research. The researcher selected you to participate in the study because you are a key official supporting smallholder farmers in water and climate change -in your district. I will be very grateful if you agree to participate in this study by answering the interview question with my assistance. Your responses will be kept confidential and anonymous. No personal identification information, names and religion or any personal sensitive information will be requested or captured. I therefore kindly request you to complete the consent form to indicate that you have agreed to participate in this research.

1. Are you in a position to describe the roles and responsibilities of your position?
2. May you describe climate change as you experience it in smallholder water resources management context?
3. Do you think smallholder farmers' vulnerability to climate change is on the increase or decrease?
4. Based on resources, which category of farmers do you think is the most vulnerable to climate change? (A category, B1 category, B2 category, C category)
5. In your view, has climate change resulted in any opportunity for male and female smallholder farmers' water resources?

6. In your views, what constraints did climate change bring to smallholder farmers' water resources management in dry areas?
7. Is climate change information readily available for the support of smallholder water resources? Indicate sources?
8. Apart from smallholder farmers' water resources, are you aware of any other activities affected by climate change in your area?
9. What support does your organization provide to smallholder farmers in line with climate change and water management?
10. Do you have a clear plan, strategy or mandate supporting your work in climate change and water resources? Explain?
11. What capacities exist in your organization to support smallholder farmers' climate change compatible water resources management?
12. Throughout the year, what roles do you play in water resources management for smallholder farmers? Kindly identify season, water supply sources, water demand and stakeholders
13. Do you have any policies or institutional arrangements that are in place to ensure climate compatible smallholder water management?
14. What are the strengths and weaknesses of these policies or institutional arrangements?
15. In your opinion, what policy gaps should be considered in future to ensure climate compatible smallholder farmers' water resources management?
16. Do you have any cases in which the following factors structure climate compatible smallholder water management?

- Indigenous Knowledge Systems (IKS)
- Traditional norms
- Gender and social norms
- Policies and legislations
- Scientific evidence
- Markets / Private Sector influence
- Natural disasters
- Government programs and
- Extension services
- Funding support

17. Are you aware of any technology that can be used to support climate compatible smallholder water resources management? Cay you list and describe their performance?
18. In your opinion, what strategies may be put in place to ensure climate compatible smallholder water resources management? Explain.

If you have anything to add or comment about this research you may kindly add.

The copy of the results of this study will be at the University Website, but if you are willing to receive a summary kindly indicate so that we can make arrangements for a copy to be delivered to you.

Annexure F2: Key informant interview guide for local community leaders

FACULTY OF HUMANITIES
SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

Key Informant Interview Guide

Local Community Leaders (Traditional Leaders and Elected Councillors)

This research assesses climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe. It aims to identifying opportunities, constraints and the role of local institutions in climate compatible smallholder water management in the dry lands. Establishing the strategies that can be adopted to improve climate compatible smallholder water management is key in this research. The researcher selected you to participate in the study because you community leader assisting smallholder farmers in the targeted community. I will be very grateful if you agree to participate in this study by answering the interview with my assistance. Your responses will be kept confidential and anonymous. No personal identification information, names and religion or any personal sensitive information will be requested or captured. I therefore kindly request you to complete the consent form to indicate that you have agreed to participate in this research.

1. Are you in a position to describe the roles and responsibilities of your position?
2. May you describe climate change as you experience it in smallholder water resources management context?
3. Do you think smallholder farmers' vulnerability to climate change is on the increase or decrease?
4. In your view, has climate change resulted in any opportunity for male and female smallholder farmers' water resources?
5. What capacities do men and women smallholder farmers have for implement climate compatible water resources management?
6. What limitations do men and women SHF face in implementing climate compatible water resources management?
7. In your opinion, if the current climate change situation continues unchecked, what do you think is the future of smallholder farmers' water resources?
8. Apart from smallholder farmers' water resources, are you aware of any other activities affected by climate change in your area?
9. Throughout the year, what roles do you play in water resources management for smallholder farmers? Kindly identify season, water supply sources, water demand and stakeholders

10. Do you have any policies or institutional arrangements that are in place to ensure climate compatible smallholder water management?
11. What are the strengths and weaknesses of these policies or institutional arrangements?
12. In your opinion, what policy gaps should be considered in future to ensure climate compatible smallholder farmers' water resources management?
13. Do you have any cases in which the following factors structure climate compatible smallholder water management?

- Indigenous Knowledge Systems (IKS)
- Traditional norms
- Gender and social norms
- Policies and legislations
- Scientific evidence
- Markets / Private Sector influence
- Natural disasters
- Government programs and
- Extension services
- Funding support

14. In your opinion, what year or period did smallholder farmers experienced any worst climate change impacts? You may kindly share as many as you can

- Identify years / period
- Identify the impacts experienced
- Identify who or what was affected
- May you describe what the response plan was?
- May you identify what needs to be done in future is cases of similar impacts?

15. Are you aware of any technology that can be used to support climate compatible smallholder water resources management? Cay you list and describe their performance?
16. In your opinion, what strategies may be put in place to ensure climate compatible smallholder water resources management? Explain.

If you have anything to add or comment about this research you may kindly add.

The copy of the results of this study will be at the University Website, but if you are willing to receive a summary kindly indicate so that we can make arrangements for a copy to be delivered to you.

Annexure F3: Key informant interview guide for local extension service providers

FACULTY OF HUMANITIES
SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

Key Informant Interview Guide

Local Extension Services Providers

This research assesses climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe. It aims to identifying opportunities, constraints and the role of local institutions in climate compatible smallholder water management in the dry lands. Establishing the strategies that can be adopted to improve climate compatible smallholder water management is key in this research. The researcher selected you to participate in the study because you provide extension services to smallholder farmers in the targeted community. I will be very grateful if you agree to participate in this study by answering the interview questions with my assistance. Your responses will be kept confidential and anonymous. No personal identification information, names and religion or any personal sensitive information will be requested or captured. I therefore kindly request you to complete the consent form to indicate that you have agreed to participate in this research.

1. Are you in a position to describe the roles and responsibilities of your position?
2. May you describe climate change as you experience it in smallholder water resources management context?
3. Do you think smallholder farmers' vulnerability to climate change is on the increase or decrease?
4. Based on resources, which category of farmers do you think is the most vulnerable to climate change? (A category, B1 category, B2 category, C category)
5. In your view, has climate change resulted in any opportunity for male and female smallholder farmers' water resources?
6. In your views, what constraints did climate change bring to smallholder farmers' water resources management in dry areas?
7. Do you have cases of smallholder farmers water management related activities that were affected by climate change?
8. In your opinion, if the current climate change situation continues unchecked, what do you think is the future of smallholder farmers' water resources?
9. Is climate change information readily available for the support of smallholder water resources? Indicate sources?

10. Apart from smallholder farmers' water resources, are you aware of any other activities affected by climate change in your area?
11. Throughout the year, what roles do you play in water resources management for smallholder farmers? Kindly identify season, water supply sources, water demand and stakeholders
12. Do you have any policies or institutional arrangements that are in place to ensure climate compatible smallholder water management?
13. What are the strengths and weaknesses of these policies or institutional arrangements?
14. In your opinion, what policy gaps should be considered in future to ensure climate compatible smallholder farmers' water resources management?
15. Do you have any cases in which the following factors structure climate compatible smallholder water management?

- Indigenous Knowledge Systems (IKS)
- Traditional norms
- Gender and social norms
- Policies and legislations
- Scientific evidence
- Markets / Private Sector influence
- Natural disasters
- Government programs and
- Extension services
- Funding support

16. In your opinion, what year or period did smallholder farmers experienced any worst climate change impacts? You may kindly share as many as you can

- Identify years / period
- Identify the impacts experienced
- Identify who or what was affected
- May you describe what the response plan was?
- May you identify what needs to be done in future is cases of similar impacts?

17. Are you aware of any technology that can be used to support climate compatible smallholder water resources management? Cay you list and describe their performance?
18. In your opinion, what strategies may be put in place to ensure climate compatible smallholder water resources management? Explain.

If you have anything to add or comment about this research you may kindly add.
The copy of the results of this study will be at the University Website, but if you are willing to receive a summary kindly indicate so that we can make arrangements for a copy to be delivered to you.

Annexure F4: Key informant interview guide for community based organization/local NGO

FACULTY OF HUMANITIES
SCHOOL OF GEOGRAPHY, ARCHEOLOGY AND ENVIRONMENTAL STUDIES

Key Informant Interview Guide

Community Based Organization / local NGO officials

This research assesses climate change compatible smallholder water management strategies in southern dry lands of Zimbabwe. It aims to identifying opportunities, constraints and the role of local institutions in climate compatible smallholder water management in the dry lands. Establishing the strategies that can be adopted to improve climate compatible smallholder water management is key in this research. The researcher selected you to participate in the study because an official of a Community Based Organization or local NGO assisting smallholder farmers in the targeted community. I will be very grateful if you agree to participate in this study by answering the interview questions with my assistance. Your responses will be kept confidential and anonymous. No personal identification information, names and religion or any personal sensitive information will be requested or captured. I therefore kindly request you to complete the consent form to indicate that you have agreed to participate in this research.

1. Are you in a position to describe the roles and responsibilities of your position?
2. May you describe climate change as you experience it in smallholder water resources management context?
3. Do you think smallholder farmers' vulnerability to climate change is on the increase or decrease?
4. Based on resources, which category of farmers do you think is the most vulnerable to climate change? (A category, B1 category, B2 category, C category)
5. In your view, has climate change resulted in any opportunity for male and female smallholder farmers' water resources?
6. In your views, what constraints did climate change bring to smallholder farmers' water resources management in dry areas?
7. Do you have cases of smallholder farmers water management related activities that were affected by climate change?
8. In your opinion, if the current climate change situation continues unchecked, what do you think is the future of smallholder farmers' water resources?
9. Apart from smallholder farmers' water resources, are you aware of any other activities affected by climate change in your area?

10. What support does your organization provide to smallholder farmers in line with climate change and water management?
11. Do you have a clear plan, strategy or mandate supporting your work in climate change and water resources? Explain?
12. What capacities exist in your organization to support smallholder farmers' climate change compatible water resources management?
13. Throughout the year, what roles do you play in water resources management for smallholder farmers? Kindly identify season, water supply sources, water demand and stakeholders
14. Do you have any policies or institutional arrangements that are in place to ensure climate compatible smallholder water management?
15. What are the strengths and weaknesses of these policies or institutional arrangements?
16. In your opinion, what policy gaps should be considered in future to ensure climate compatible smallholder farmers' water resources management?
17. Do you have any cases in which the following factors structure climate compatible smallholder water management?

- Indigenous Knowledge Systems (IKS)
- Traditional norms
- Gender and social norms
- Policies and legislations
- Scientific evidence
- Markets / Private Sector influence
- Natural disasters
- Government programs and
- Extension services
- Funding support

18. Are you aware of any technology that can be used to support climate compatible smallholder water resources management? Cay you list and describe their performance?
19. In your opinion, what strategies may be put in place to ensure climate compatible smallholder water resources management? Explain.

If you have anything to add or comment about this research you may kindly add.

The copy of the results of this study will be at the University Website, but if you are willing to receive a summary kindly indicate so that we can make arrangements for a copy to be delivered to you.

Annexure G: Research Gallery – Fieldwork and data analysis in pictures

Chiredzi Data Collection – Photo Gallery (October - December 2020)

Observing COVID-19 Protocol during research – participants' hand sanitization

DRR Committee – Focus Group Discussion participants in ward 2

Field Observation - Muteyo Water Point, ward 25

Field Observation - Rupangwana Irrigation, ward 4

End of Data collection - Chiredzi district
Left to Right: Mr. Tizai (AGRITEX Supervisor), Augustine Mureri (Research Assistant), Mr. Ignatius Chorira (Women Affairs), Pascal (PhD Candidate), and Mr Sams Takaniza (District Head, DDF)

Zvishavane Data Collection – Photo Gallery
(November 2020 – January 2021)

Fieldwork: Mahlaba supplementary dam, ward 15 Zvishavane, Date: 17 December 2020

Marirangwe Wetland in Zvishavane ward 17, Date: 09 January 2021

Field Measurements - Hydrogeological analysis of Marirangwe wetland - 09 January 2021

Data Analysis and Report Writing – Photo Gallery
(Starting November 2020)

Data analysis **Source: Author, March, 2021**

Data analysis **Source**: Author, June 2021

Data analysis **Source**: Author: July 2021

Report Writing Retreat– Photo Gallery
(November 2021)

Report Writing Retreat - Encounter with Elephants at Antelope Park in Gweru
Source: Author, November 2021

Report writing retreat at Antelope Park in Gweru
Source: Author, November 2021

Annexure H: Journal Article Submission

Manyakaidze, P.; Simatele, M.D.; and Musavengane, R. (under review). ***Groundwater development and management constraints in drought prone Chiredzi and Zvishavane Districts****. Climate Risk Management, Impact Factor 5.266, Citation Score 5.7, Elsevier.*

Climate Services

Groundwater development and management constraints in drought prone Chiredzi and Zvishavane Districts

--Manuscript Draft--

Manuscript Number:	CLISER-D-22-00189
Article Type:	Research paper
Keywords:	Climate change; Drought prone; Groundwater; Hydrogeology; Water management
Corresponding Author:	Pascal Manyakaidze University of the Witwatersrand Johannesburg Johannesburg, SOUTH AFRICA
First Author:	Pascal Manyakaidze
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	Regis Musavengane
	Mulala Danny Simatele, PhD
Abstract:	Communities in drought-prone areas continued to fall into new vulnerability traps due to increasing water demand and stress. The study aimed to assess groundwater development and management constraints in Chiredzi and Zvishavane districts. Groundwater development and management activities implemented in the study area were supported by the Government of Zimbabwe, development private sector players. Interpretivism and realism philosophical positionalities were employed in the study. Whilst interpretivism enabled in-depth qualitative methodology and understanding of the groundwater constraints, the direct realism provided quantitatively driven scientific and statistical data answering research questions exhaustively. Quantitative data was gathered through household questionnaire administered randomly to selected respondents. Focus group discussions, direct field observations, key informant interviews, and measurements were employed in qualitative data collection. Respondents of key informant interviews were drawn from district-level government officials, local authorities, traditional leaders, village pump minders and water point committee members. Droughts brought by changes in climate reduced groundwater availability and increased seasonality of groundwater sources. Rising temperature and declining rainfall reported ny by 97%, and 73% of respondents contributed to reduced groundwater recharge and increased withdrawal. Over 85% coverage of Chiredzi and Zvishavane are covered by low-yielding basement hydrogeological formation. Village Pump Minders and Water Point Committees reported operational and maintenance challenges due to weaker institutional arrangements and funding models. The study recommends an ecosystems-based groundwater replenishment model and strengthening local institutional capacity to improve aquifer recharge, water storage and management to promote integrated water resources management by balancing groundwater supply and demand.

Annexure I: **Turnitin In Report (25 November 2022)**

PascalManyakaidze_985959_Thesis_25-Nov-2022_final.docx

ORIGINALITY REPORT

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SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

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