UNIVERSITY *of the* WESTERN CAPE

ASSESSING RURAL DOMESTIC WATER DEMAND AND USE FOR LOCAL GROUNDWATER GOVERNANCE DURING DROUGHT, HA-LAMBANI AREA, SOUTH AFRICA

By

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A thesis submitted in partial fulfilment of the requirements for the degree of Magister Science in the Department of Earth Science, Environmental and Water Sciences, Faculty of Natural Sciences, University of the Western Cape.

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DECLARATION

I declare that *Assessing rural domestic water demand and use for local groundwater governance during drought, Ha-Lambani area, South Africa* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

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Full Name

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Signature

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Date

DEDICATION

This work is dedicated to my daughter (Andzani), parents, sisters and brothers

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ABSTRACT

Groundwater demand (abstraction) and use during drought continues to be a vital aspect in rural areas. However, the lack of systematic data to assess the availability, demand and use of such resource in addition to lack of having appropriate implementation plan for governing such resources at local scale especially in unmetered areas remain a problem. The argument in this study was that designing appropriate implementation plan that considers local context, informs the basis for implementing local groundwater good governance practice that would sustain utilisation and management of groundwater resources. The Ha-Lambani Village in Limpopo Province of South Africa was used as case study. The aim of this study was to assess rural domestic water demand and use that would inform a basis for designing an appropriate implementation plan for local groundwater good governance as an intervention during drought in rural unmetered areas. To achieve such an aim, i), physiographic factors that influence groundwater availability were explained to establish availability of groundwater; ii), rural domestic water demand and use were assessed to showcase the procedure of generating quantitative data on groundwater abstraction and consumption; iii), factors that determine rural domestic water demand and use were established; iv), appropriate implementation plan for local groundwater governance was designed with evaluation indicators built in. The capability, resilience and sustainable livelihoods approaches were applied as theoretical and conceptual frameworks for the study which informed better understanding of coping strategies during drought.

In this study, both qualitative and quantitative methodologies were used. For qualitative methodology, individual interviews such key informant interviews, focus group discussions (FGDs) and observations were used to collect qualitative data whereas interpretative methods and analytical method were used to analyse the collected information. In addition, the content- thematic analysis was used to analyse the qualitative data focusing on context matters approach. For quantitative methodology, household survey, indirect method and field observations were used to collect the quantitative information with a purposive sampling techniques of 92 household participants. Indirect quantitative methods for computing water demand and use and multiple regression analysis for determining factors for water demand and use were used. First the objective, the qualitative assessment using physiographic factors showed that the studied area had limited amount of groundwater. Based on these findings, the current study recommends quantitative methods for assessing groundwater recharge. For the

second objective, the study showed that the amount of groundwater that was abstracted from the source was 116.91 litres per household per day and out of that abstracted water, only 92.55 litres were used per household per day leaving 24.36 litres of water that was abstracted but not used. Nevertheless, when daily statistics were extrapolated on monthly basis, the demand for water was 3,507.30 litres per household and water use was 2,776.5 litres per household. When such figures were further extrapolated on yearly basis, water demand was 42,087.6 litres per household while water use was 33,318 liters per household. These findings confirmed that demand for water is usually higher than the actual water usage, an aspect that requires appropriate implementation plan to govern such water abstraction at local source. Such a plan would reduce the demand for such water, thereby informing the basis for sustainability. Although the method that was used was crude, but it provided a starting point of showing how statistical information can be generated on water demand and use especially in unmetered rural areas. The multiple regression analysis showed that the full model was statistically significant at 5% level where household size was statistically significant at 5% (0.020) for water demand and (0.008) for water use model. However, only 12% and 15% of factors in the model explained the demand and use of water at household level respectively in rural unmetered areas as shown by the values for adjusted R Squared in the multiple regression model analysis. The study recommends the direct and indirect methods for comparative analyses for reliability and validity. In objective three, thematic content analysis was used and the results showed that governance provisions at local level for the study area appeared to be to be insufficient in dealing with the prevailing effect of drought, suggesting that a detailed study is required to interrogate ways of making such provisions address the inefficiency. This study recommends that a better strategic selection of parameters for such a study needs to be implemented which consider backward and forward statistical analyses during computational processes.

In objective four, using Ostrom design principle were applied to evaluate the feasibility of using such principles in the study area, results showed such principles were not feasible in Ha-Lambani Village regardless of empirical evidence of successful application of such principles in many areas as show by reviewed literature. From these results it is recommended that a detailed field observations with subsequent consultative meetings with all stakeholders is required for adequate assessment of the application of the principles. In objective five, results showed that such application was proved successful in the present study when it was applied in the Ha-Lambani Village. This study recommends a community engagement plan that will sustain local participation and initiatives as proxy for the full and successful groundwater governance at local scale i.e. the community. The sustainable livelihoods approach was applied alongside the capability and resilience approaches in pursuit to answer the research question of the present study which was what people do to adapt or sustain their water demand and use livelihoods with the aim of designing an implementation plan that ensures local governance intervention of groundwater resources during drought events in rural areas. The results showed that relevant officers for Thulamela Local Municipality and Vhembe District Municipality would need to be represented in groundwater governance and management committees at all levels to input into decision-making process towards implementation of such decisions at local levels where actions matter. Secondly, the Ha-Lambani Village as a community had committees with operational rules on water utilization and management which were part of the with Ostrom design principles of good governance in water resources at local level. Therefore, in can be concluded that application of capability, resilience and sustainable livelihoods approaches as a feasible plan for better understanding coping strategies during drought events was fulfilled.

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CHAPTER 1: GENERAL INTRODUCTION

1.1 Overview of the study

This study was about assessing rural domestic water demand and use in order to develop an implementation plan that ensures the operation of good governance on groundwater at local scale. Multi-method approach was employed whereby quantitative and qualitative methods were used to collect and analyse data. The argument in the present study was that designing appropriate implementation plan that considers local context, enables local groundwater good governance practice for sustainable utilisation and management of water resources. The study furthers argues that for such a plan to be designed data on water demand and use must be available and for such data to be available at local scale in unmetered rural areas, a practical approach or procedure on how to generate such data must be demonstrated. The Ostrom design principles of governance were used to assess feasibility of such principles in vulnerability context of drought in the study area. The used the capability and sustainable livelihood approaches as theoretical framework in addition to using the concept of resilience as conceptual framework of the study to understand how people adapt to effects of drought in unmetered rural setting. As a showcase, the thesis demonstrates how data on groundwater abstraction and consumption at sub-village or village levels can be generated for wider replication in the discipline of water demand and use assessments among other analyses. Ha-Lambani Village in Limpopo Province of South Africa was used as a case study.

Globally, most commonly used drought indicators are being applied across drought-prone regions with the aim of advancing monitoring, early warming and information delivery in supporting risk-based drought management policies and preparedness plans (WMO & GWP, 2016). Drought events and their effects or impact on water resources continue to be felt by different sectors especially in rural areas regardless of the interventions by various stakeholders. Unfortunately with climate variability, drought is likely to become more frequent. However, it is crucial to assess the viability of scaling up successful local solutions as well as identifying new solutions that work in certain context (WRC, 2016). Therefore, it is compelling to provide a method of generating quantitative data for assessing domestic water demand and use that ensures that local groundwater governance practice during drought are operational especially in rural areas when drought effects are felt the most. In this study, domestic water demand and use was used as a case study to showcase the alternative approach on data generation that has potential for wider implementation beyond the studied household and village levels. As climate variability such as drought continue to be predicted to affect future supply and demand for water resources, new methods for generating data to continuously assessing availability, demand and use of water resources remains crucial.

The present study in Ha-Lambni Village, Vhembe District in Limpopo Province of South Africa was motivated by the 1) existing limited water resources in the area which increases their vulnerability to impacts of climate variability regardless of the prevailing water policies and laws that promote access to water resources; 2) lack of a case study to show the procedure to enable data availability on water resources especially on groundwater that would inform the basis to implement water policies and laws; and 3) lack of implementation plan and limited efforts by stakeholders to ensure that local groundwater governance practice during drought are operational especially in rural areas when drought effects are felt the most.

1.2 Background to the study

The global situation on water demand and use from drought perspective remains negative. For example, water availability continues to be affected negatively by effects of climate variability such as drought. In some regions, this is a major challenge especially in rural areas because of limited availability of water resource in addition to lack of services from water supply authorities of many governments globally. Negative impacts of climate change and climate variability are felt in many parts of the world. On global scale, the IPCC, (2007) mentions Europe, Africa, Asia, and South America, Australia and New Zealand as regions which continue to be affected by negative impact on climate variability on water resource availability. Globally, groundwater and surface water sources are projected to decline by 2030 thereby affecting water availability for human consumption. The demand for water and use will further impact on several human activities thereby sustainable livelihoods of such people in various places of the globe (IPCC,2007, IPCC, 2014).Drought is one of the main examples of climate events that affect rural communities for water demand and use. Such event in Africa has been extensively researched, particularly from meteorological, agricultural, and food security perspectives. However, the impact of drought on groundwater demand and use in unmetered rural areas or communities has received less attention in terms of publication. In addition, the focus on local groundwater governance and implementation plan for governing, using and managing of such resources. Although the use of sustainable livelihoods approach (SLA) has received wider application especially in agriculture and development studies, such approach has not been used as an analytical framework for groundwater demand and use in unmetered rural areas from vulnerability context of drought and variable of climatic change variability. For example, drought as one of the extreme climatic condition has shown worse scenario for Africa, as there is an expected water stress increase due to climate change by 2020 and between 75 and 250 million people are projected to be exposed to increased water stress due to climate change (IPCC, 2007).

Masih, et al (2014) report that most studies in Africa indicate that droughts have become more frequent, intense and widespread during the last 50 years. For example, the extreme droughts of 1972–1973, 1983–1984 and 1991–1992 were continental in nature and stand unique in the available records. In addition, many severe and prolonged droughts were recorded in the recent past such as the 1970s -1980s droughts in western Africa, 1999–2002 drought in northwest Africa (Sahel), in 2001–2003 drought in southern and south-eastern Africa, and 2010–2011 drought in eastern Africa (Masih, et al ,2014). The present study argues that there is a need to generate data and apply analytical framework that will assist in designing implementation plan for local groundwater governance for rural unmetered areas to provide basis for sustainable utilization, management and governance of such waters. The studies conducted in Ethiopia, Mozambique, Botswana, Namibia, Zimbabwe are the example of drought situation with its impacts on the livelihood (Runtunuwu, 2005). Drought can be described as a sustained and extensive occurrence of below average natural water availability, and can thus be characterized as a deviation from normal conditions of variables such as precipitation, soil moisture, groundwater and stream flow (Loukas & Vasiliades, 2004). Drought is a recurring event in Africa based on observations from North African, Eastern, and Southern Africa countries among others.

Climate change presents a major concern for the availability, access and quality of water resource, particularly in South Africa (Ziervogel et al, 2010). By 2080, an increase of 5 to 8 percent, the arid and semi-arid land in Africa is projected to experience a range of water insecurity (IPCC, 2007), which is a threat especially for the rural population whom continue to receive poor service delivery such as water supply. While the globally statistics show that in developing countries, about 1.6 billion people have gain access to safe rural domestic water supply since 1990 (Ahiablame et al 2011), such successes are likely to retrogress with projected negative effects of climate variability such as droughts in many parts of the work including South Africa were the present study was conducted. For example South Africa continues to be categorised as water scares country. Therefore the need to design a tool that enables sustainable utilization, management and governance of groundwater resources especially in rural unmetered areas remain critical and therefore data need to be generated to inform intervention in such areas to sustain the majority of people who reside in such vulnerable areas. This situation informed the need to for the present study to design an implementation plan for local groundwater governance that would enhance the monitoring and abstraction of groundwater resources during drought periods.

In southern African region, estimating domestic water demand and use at a catchment level for rural areas in southern Africa is problematic due to the lack of measured data available. Such estimations of rural domestic water demand and use is complicated (Molden, 2007; Healy 2010; Brown & Matlock, 2011) especially at local level household for rural unmetered in the context of drought. Therefore, providing a crude method on generating data on groundwater demand use was thought useful as a proxy of the real-time data collection. For example, several scholars highlighted the complexity for estimating rural water demand and use because 1) most rural domestic water supply systems are unmetered; 2) Data on domestic rural water demand and use are often expensive and time consuming to collect; 3) The level of service provided by the water supply system is often unknown (Molden, 2007; Healy 2010; Brown & Matlock, 2011). Such complex informed the current study to provide a method on how to collect and establish water demand and use in unmetered rural areas on groundwater. Such estimation was thought to provide a basis designing implementation plan for local groundwater governance to manage and sustain such resource future use.

In addition to data limitation on groundwater resource, South Africa has prioritized the same resource for allocation for various water demands and uses at different levels within the water reform framework where water use entitlement such as schedule one for domestic water use, general water authorisation, existing water use and compulsory water licensing are meant to be realised (Münch & Conrad, 2007; Rogers & Hall, 2007; Bakker et al., 2008). These water entitlements entail implementation of water governance regulations and institutions with clear operational rules. Some of the challenges for groundwater governance regimes in South Africa and beyond that need to be addressed include institutional and political aspects such as fragmented and overlapping jurisdictions and responsibilities, competing priorities, traditional approaches, rights and water pricing systems, and diverging opinions (Loucks (2000), Council of Canadian Academies, 2009). Although the governance of such resources is important implementation plan with inbuilt monitoring evaluation and reporting tools for local groundwater governance remain unavailable for stakeholders for use. This informed the basis of the present study to design such tool using design principles of good governance. The current study argues that the assessing application of the design principles of good governance provides a platform for designing implementation plan with built-in monitoring, evaluation and reporting tools to sustain the livelihoods of people who are affected by effects of negative climatic variability such as drought especially in rural settings of South Africa.

1.3 Problem statement of the study

The lack of systematic data to inform appropriate implementation plan for local groundwater good governance for rural unmetered areas remain a problem. This is a problem because the assessment of water demand and use requires quantitative data on water abstraction and consumption. In addition, the implementation plan is a practical tool that institutions such as water committee require to oversee the process of generating data on water demand and use. One of the solutions for such problem is to design appropriate implementation plan for local groundwater good governance in rural unmetered areas that will ensure data is collected to facilitate assessment of abstraction and consumption of such waters.

The absence of systematic data on groundwater demand and use as one of the major problem in managing water resources has already been reported (Molden, 2007; Healy 2010; Brown & Matlock, 2011). In terms of scale the problem is local, regional and global. For example, Vorosmarty et al. (2005) support the widely cited threshold of the Falkenmark indicator and hesitate to recommend using the model by Yang et al. (2003) which does not include information on groundwater due to lack of systematic data. The current study aimed to contribute this aspect by proving the methodology on how to systematically generate data on groundwater in unmetered rural areas using Ha-Lambani Village as a case study to inform design appropriate plan for good local governance and management of groundwater resources especially during drought (vulnerability context). This aspect on how to generate data on groundwater abstraction and consumption has been addressed by objective two of current study and results on such objective are presented and discussed in chapter four.

In addition, quantitative data on water abstraction (demand) and consumption (use) from a borehole or well point source is lacking to feed into the national database such as the national Groundwater Archive (NGA) in South Africa context and global database such as AQUASTAT require quantitative data on groundwater abstraction and consumption. The definitions of water use exist but the current study used the definition of Vorosmarty et al., (2005) who states that water use refers to total water withdrawals for domestic. A watershed sustainability index for water use was developed by Chavez & Alipaz (2007) who suggested hydrology, environment, life and policy as parameters for their model. McNulty et al., (2010) developed the water supply stress model to quantitatively assess the relative availability of water supply and demand at watershed level. The use of both models depends on availability of information specific to river catchments which are scarce in many regions (Brown & Matlock, 2011) hence the limitation to apply such models. This justifies the assumption for the current study to provide a method of generating data on water demand and use at village level Village focusing on sub-communities in Ha-Lambani Village. To date, studies on quantifying groundwater abstraction and consumption at borehole level are scarce and yet quantitative data on groundwater demand and use are required for decision-making on water supply especially during drought events. In addition, models require quantitative data on groundwater demand and use to calibrate and validate their models. Therefore, the second objective of this study which focuses on showcasing how such quantitative data on groundwater demand and use can be generated at borehole site is fundamental aspect.

1.4 Research question and thesis statement

The main research question for this study was: What implementation plan is appropriate for local groundwater good governance in rural unmetered areas? To answer this question, five sub-research questions were formulated in line with each study objective in section 1.5 as follows: 1. To what extent do physiographic factors explain groundwater availability in a chosen area?; 2. How do indirect methods provide assessment of water demand and use in an area? 3; What are the key factors that influence water demand and use?; 4. To what extent do

Ostrom design principles assist in designing appropriate implementation plan for local water good governance practice? and 5. In what ways does application of capability, resilient and sustainable livelihood approaches assist in understanding how households cope with drought events that threaten their domestic water supply?

The main thesis statement or central argument for this study was that designing appropriate implementation plan that considers local context enables local groundwater good governance practice for sustainable utilisation and management of water resources. To prove this argument successfully, five sub-thesis statements were formulated in line with each study objective in section 1.5 as follows: 1. Qualitative assessment of how physiographic factors influence groundwater availability in an area provides key insight whether or not a particular area has adequate groundwater resource for abstraction or not; 2. Establishing water demand and use in a particular area depends on available data on water demand and use variables; 3.The use of regression analysis model provides insight on that factors that are statistically significant to explain the demand and use of domestic water in a particular area; 4. A plan that considers local context enables good local governance practice for water demand use; and 5. Using theoretical frameworks for water demand and use provides key insights on what people do to adapt to effects of climate variability such as drought.

1.5 Study aim and objectives

The aim of the study was to assess rural domestic water demand and use that would inform a basis for designing an implementation plan for local groundwater good governance as an intervention during drought in rural unmetered areas. Ha-Lambani Village in Limpopo Province of South Africa was used as case study. This study was informed by capability, resilience and sustainable livelihood approaches as both theoretical and conceptual frameworks. These approaches assisted in understanding the coping mechanisms practiced by rural households during extreme weather events such as drought.

To achieve the study aim stated above, the objectives of the current study were to:

1. Explain the influence of physiographic factors on ground water availability
2. Assess rural domestic water demand and use using indirect methods
3. Determine factors for rural domestic water demand and use using regression analysis

4. Explore appropriate implementation plan for local groundwater governance using Ostrom design principles of good governance for domestic water demand and use
5. Assess application of capability, resilience and sustainable livelihoods approaches as a feasible framework for better understanding coping strategies during drought events

1.6 Study rationale/implication of the study

Based on the description of the research problem to this study and the situational analysis presented in the background section to this study, it is hoped that the findings of this study will provide a better understanding of water availability, demand and use especially in the vulnerability context of drought in rural areas where water abstraction is not metered. As a starting point, findings of this study serves as teaching and learning materials for educators and learners; provide records for literature review for further studies on a similar study topic; provide a platform for refining a suggested methodological approach on generating quantitative data for water demand and use assessments from boreholes or water points at sub-village, village, sub-catchment or catchment levels; provide an example on how to design an implementation plan that has potential to facilitate the working local groundwater good governance in rural areas during drought events. In general results of this study provides a basis for recommending both technical and policy briefs that would trigger interventionists such as non-governmental organisations (NGOs) and Government departments to implement an intervention plan that ensures feasible operation of good governance for groundwater at a local scale. The results confirm that context matters and the setting remain crucial in studies.

Above all the current study contributed to a journal article entitled "Towards ethnography of climate change variability: perceptions and coping mechanisms of women and men from Lambani Village, Limpopo Province. The author of this thesis, Ally Hanyani Lebese, is one of the authors of the journal article which has been accepted in a peer- reviewed Journal of Human Geography: A Radical New Journal to be published in 2017. The authors are Goldin, J., Botha, J.J., Koatla, T.A.B., Anderson, J.J., Owen, G., & Lebese, A.

1.7 Scope and nature of the study

The subject of water use is usually categorized in four main spheres namely: 1) Domestic water use; 2) industrial water use; 3) agricultural water use and 4) environmental water use. The current study focused on domestic water use which refers to water used for indoor and outdoor household purposes including drinking, preparing food, bathing, washing clothes and dishes, watering the yard and garden among other uses. Although industrial, agricultural and environmental water uses are critical for socioeconomic growth and environmental integrity of different countries, the current study did not focus on such aspects. Water demand and use as a subject can cover various aspects but the current study focused on factors that explain availability of such water and factors that explain demand and use of such water including demonstrating practical procedure that can be used to measure volume of water abstracted from sources and consumed at household levels in a studied village. The sources of water for domestic water demand and use can be numerous, but the current study focused on groundwater sources only. Water demand and uses can be assessed at global, regional, country or catchment levels but for the current study, the analysis was conducted at village level with the aim of proving an insight about the feasibility of the approached used.

The nature of the study is largely a qualitative study which draws on quantitative results of objectives 2 and 3 to design an implementation plan. The discussion on the use of mixed methods approach has been presented in the methodology chapter. Nevertheless, the research design for the current study is the descriptive observational research design which uses both quantitative and qualitative methods of data collection and analysis. In general the present study followed a case study approach and Ha-Lambani Village in Limpopo Province of South Africa was used a case study to illustrate the practical procedure on generating data on water demand and use especially in unmetered rural areas thereby contributing to providing solution on the global problem of data scarcity on groundwater abstraction and consumption.

1.8 Study context: The water research commission project

The current study was part of the bigger Water Research Commission project (WRC) funded Project: K5/2314, entitled “Towards gender-sensitive strategies for responding to challenges posed by climate related impacts”. The WRC Project aimed at designing a gender mainstreaming framework. To achieve such aim, the projects had the following objectives: 1) investigated enabling factors and that influence women’s participation in decision-making process within the water; 2) Conducted a pilot study vulnerability assessment of rural women under changing climatic conditions; 3) Explored challenges that women encounter around water security; 4) Evaluated the extent to which policy frameworks and strategies that addressaccesstoresourcesaregendersensitive,5)identifiedbarrierstowomen’saccessto resource such as land, water and finance and recommend how these could be addressed and 6) Designed a framework for mainstreaming gender into climate change adaptation by assessing institutionalisation of good practice in policy. For each these objectives, a deliverable report was prepared and submitted to WRC Office and the author of this thesis contributed to such deliverables.

The argument in the WRC Project was that women's limited access to resources and decision-making processes increases their vulnerability to impacts of climate change. The WRC project was implemented in Ha-Lambani Village and focused in the following aspects of climate change, floods and droughts, changing hydrologic regimes and intensified hot or cold periods. In terms of methodological approach, the WRC project followed mixed methods whereby quantitative methods such as household survey interviews using questionnaire as an instrument were used as well as qualitative methods such as focus group discussions interviews, key informants interviews and observation. The quantitative methods and data were used to validate qualitative methods and data. Primary and secondary data were generated and analysed using quantitative and qualitative methods and tools.

The current study was also implemented Lambani Village which local residents fondly call it Ha-Lambani Village. The multi-method approach of the main WRC project was adopted for this thesis work. The setting of rural area and the context of vulnerability were similar to the WRC project which funded the field work of the study. However, the study for the thesis focused on drought only as a component of climate change. The study also focused on groundwater resources only. In addition, the problem statement, the research question, research hypothesis, study aim were not the same as for the WRC project thereby making the study for the thesis unique and original in design from such perspective.

The current study used the same study area, Ha-Lambani Village, but the problem statement, research question, research hypothesis (thesis statement (research hypothesis), the study aim and its objectives were not the same although the researcher contributed to writing deliverables for the bigger WRC project. It is important to note that the data from the current study for the thesis contributed to a journal article entitled "Towards ethnography of climate change variability: perceptions and coping mechanisms of women and men from Lambani Village, Limpopo Province". This paper has been accepted in the peer-reviewed Journal of Human Geography: A Radical New Journal for publication. The authors are Goldin, J., Botha, J.J., Koatla, T.A.B., Anderson, J.J., Owen, G., & Lebese, A.

1.9 Thesis outline

This thesis is divided in 8 chapters as follows: Chapter 1 provides the general introduction of the study where the problem statement is described; the researched question asked; the thesis statement presented; study aim and objectives presented, the scope of work and nature of the study delineated to guide the reader on the focus of the work. Chapter 2 presents the theoretical framework that informed the study in addition to presenting the reviewed literature that shows the known versus the unknown on the study topic in South Africa and beyond. Chapter 3 describes how the research was conducted detailing the methods and procedures for data collection and analysis in addition to discussing the research design that was adopted and the methodology that was followed. Chapter 4 on rural domestic water demand and use first, discussed factors that influence groundwater availability using physiographic factors; then assessed rural domestic water demand and use using indirect methods; finally, determined factors that explain rural water demand and use using regressions methods. Chapter 5 on implementation plan for local groundwater governance for rural domestic water demand and use designed the appropriate implementation plan for local groundwater governance using Ostrom design principles of good governance for domestic water demand and use. Chapter 6 on demonstrated the application of capability, resilience and sustainable rural livelihoods approaches as a feasible framework for better understanding coping strategies during drought events especially in unmetered rural areas. Chapter 7 provides the conclusions and key suggestions for further studies on water demand and use in rural areas during extreme events.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The first chapter has provided the general introduction of the present study. The present chapter provides a review of literature on what is known and what is not known about the collaborative use of capability approach (CA) and resilience concept (RC) and sustainable livelihood Approach (SLA) from a qualitative perspective in understanding the coping mechanisms practiced by rural households during extreme weather events such as drought by assessing domestic water demand, use and its governance. The objective is to show how the use CA, RC and SLA have been used to provide solutions in similar settings during drought. To achieve such an objective, studies carried out in South Africa and beyond on domestic water demand, use and governance during drought events have been reviewed. In addition, reliable sources and coping strategies that people use when they experience drought events have been systematically and analytically reviewed shedding light on the lessons learned and areas that require improvements. The research framework that shows the progression of the present study has been presented with a summary of key gaps that need to be addressed.

2.2 Climate change and water resources

Climate change presents a significant concern for the availability, access and quality of water resources, particularly in Africa (Ziervogel et al., 2010). South Africa on the continent is generally a semi-arid to arid country which experiences a highly variable climate and limited freshwater resources (Adewumi, 2010). With such limitation water resources are vulnerable to the occurrence of extreme weather conditions, often caused by climate variability and change. Droughts are an example of such extreme events weather conditions, which the potential result in to the significant adverse socio-economic impacts.

South Africa is vulnerable to the occurrence of drought as the results of its location, topography and generally low rainfall (national annual rainfall average of approximately 500mm) (LeComte, 2016). During 2015-2016 the country has been severely affected by the El Nino drought, the adverse effects of which are still being experienced (LeComte, 2016). Long-term rainfall records collected by the south Africa weather services (SAWS) indicates that the annual total rainfall for south Africa for the period January-December 2015 (403mm), has been the lowest since 1904. This current study argued that water resource has been significant pressured by the occurrence drought for supply and use, especially in rural areas.

Drought is a recurring event in Africa by viewing on the ongoing of such events for example in Ethiopia 2002 and 2003 drought, affect large swathes of eastern and southern Africa, it is not exceptional. For example, studies conducted in Ethiopia, Mozambique, Botswana, Namibia, Zimbabwe are showing evidence on the droughts impacts on the rural livelihood (Runtunuwu, 2005). South Africa drought is unique phenomenon that is not merely affecting activity on agriculture however also on rural domestic water demand and use contributing society. Drought can be describes as a sustained and extensive occurrence of below average natural water availability, and can thus be characterized as a deviation from normal conditions of variables such as precipitation, soil moisture, groundwater and stream flow (Loukas & Vasiliades, 2004). Groundwater resource in alternated source and require protection and monitoring for sustainable use, at household local level in unmetered rural areas by putting appropriate plans in places that manage the abstraction (demand) and use (consumption).

The conclusion has been made by the researchers that climate change threatens South African's suitable function ecosystems(Bennettetal., 2015),while drought events continue to have dramatic impact on society in terms of livelihoods and environmental losses (Aldunce et al, 2014). Although droughts are being contested with reactive measures and attention is being given to the quantity of water available to communities (Shrestha et al., 2014), the Local groundwater governance is being neglected by local administrations in some region. Lack of appropriate implementation plans for local groundwater governance to monitor and maintain adequate water resources at a household level is evident in most cases. Furthermore, in most of the villages, users are unaware of local groundwater good governance which manages the rural water demand and use supplied to them from water source/point. Under drought conditions, the abstraction (demand) of water tends to be overlooked, especial to rural unmetered area. Hence, it is essential to assess rural domestic water demand and use in order to design appropriate implementation plan for local groundwater good governance to those rural communities in drought-prone with unmetered.

2.3 Overview of global and South African water sector

Globally, Groundwater resource is a major source of water particularly in rural areas in arid and semi-arid regions for rural households use, but there has been very little on the potential effects of climate change on it (IPCC, 2001&BGR, 2008) such drought events. Utilisation of such resource is categorised as the following uses; agricultural, industrial, domestic, mining and environmental use. With such various uses, groundwater resource still plays crucial role on rural household for domestic water demand and use, one third of the world's population depends on such resource in both urban and rural areas. However, Groundwater can be influenced by recharge mechanism since it is one of the ways groundwater level can be fulfilled. Groundwater abstractions (demand) that exceed the average recharge, results in a continuing depletion of aquifer storage and lowering of the groundwater table. Natural occurrence of safe yield for groundwater can be withdrawn from an aquifer on a sustained basis, economically and legally, without degradation and exploding the resource. Hence such practice required appropriate implementation plan for local groundwater governance to monitor and manage at a household local scale in rural areas.

Groundwater occurrence is mainly governed by geology, degree of fracture and topography. The low lands, mainly the rift valley areas, are characterized by a relatively high potential of groundwater availability (Xu & Beekman, 2014). Hydrological cycle distributes rainfall differently based on various factors geographical position that can affect the availability water and its distribution around the globe (IPCC, 2008). Climate change will lead to an intensification of the global hydrological cycle and is likely to have major impacts on regional groundwater and surface water for rural water supply for domestic demand and use. Changes in the total amount of precipitation and in its frequency and intensity directly affect the magnitude and timing of droughts (IPCC, 2007). The thesis argued that explaining influence physiographic factors on groundwater availability using interpretative methods it is the first step to take before estimation on groundwater using measurements.

Such events indicate higher temperatures and reduction of precipitation levels cause shortages in available supply due to slower replenishment rates of underground water resources and/or reduced availability of surface water. These effects will be even more difficult to manage for those water utilities that are unprepared (Danilenko et al., 2010) people and ecosystems are particularly vulnerable to such condition (IPCC, 2008).

Assessment of rural domestic water demand and use would provide a basis for designing implementation plan of local groundwater good governance in rural unmetered areas in vulnerability context of drought.

2.4 Assessment of water availability, demand and use during drought event

Methods have been developed to quantitatively assess the availability, demand and use of water resources. Selecting suitable parameters for such methods has been a complex issue due to decisions that consider policy and scientific factors for agreements (Brown & Matlock, 2011). The drought event emerges as a unifying concept or situation to bring these two aspects for solution so that water resources or water supply services are governed and managed in a coordinated manner for sustainable use at household level (Hooper,2006).

The objective one of this thesis as stated in chapter one argues that a qualitative approach for assessing factors that explain water availability as an example is a starting point to bring scientists, policy makers (managers) and users together for discussion on governing and managing water resources for domestic use in a coordinated manner during drought events. As a case study approach, the current study aims to assess groundwater availability using physiographic factors from qualitative perspective to inform more quantitative assessments on the same parameters before demonstrating on how data on groundwater demand and use are generated at household level in unmetered rural areas so that and estimates that determine demand and use using regressions analysis could be computed.

For water availability, the Falkenmark indicator is the most widely used measure of water availability where countries are surveyed and water usage per person in each economy is calculated. The index threshold of between 1700 m^3 and 1000 m^3 per capita per year is used as the threshold between water abundant and water scarcity countries (Falkenmark, 1989). Individual usage is the basis for the Falkenmark indicator and the index is designed to be used in water assessment at national level where data is readily available. Using Falkenmark's benchmark, South Africa can be described as a water scarcity country with 1154 m^3 per capita per year while the neighbouring countries had 11814 m^3 (Mozambique), 1584 m^3 (Zimbabwe), 9345 m^3 (Botswana) per capita per year, and 10211 per capita per year in Namibia (FAO-AQUASTAT, 2002). The Falkenmark index is easy to understand but the use of national annual average stands to obscure important information at smaller scales and under-measure the impact of smaller population (Rijsberman, 2006). This observation informs the need for a methodology to address this aspect as shown in the present study.

Gleick (1996) developed a method to measure water demand for basic human needs where it was proposed that to meet the human basic needs; a total demand of 50 litres of water per person per day is required. The 50 litres composed of 5 litres, 20 litres, 15 litres, and 10 litres per person per day are required for drinking, sanitation, bathing and food preparation respectively. This benchmark indicator was regardless of factors that affect such demand (Gleick, 1996). In South Africa, the recommended water requirement is 25 litres per person per day but the Department of Water and Sanitation plans to adopt the global demand estimate of 50 litres of water per person per day (DWS, 2015 & DWA 2011).

Both Falkenmark's and Gleick's benchmark indicators of 1,000 m^3 per capita per year and50 litres per person per day as a standard have been accepted by the World Bank (Falkenmark & Widstrand, 1992). Therefore, international organisations, researchers and water providers are recommended to adopt these indicators as new threshold for water availability in a country and water demand per person per day to meet basic human needs (Brown & Matlock, 2011). Although the water availability figure of 1154 m^3 per capita per year for South Africa is above the lower limit of Falkenmark indicator of 1,000 m^3 per capita per year, South Africa is classified as a water scarcity country as described in several documents including (DWA 2011& DWS, 2015). Nevertheless, the minimum recommended water demand of 25 litres per person per day is below the minimum international standard of 50 litres per person per day. Total water withdrawal (abstraction) per person per year in South Africa is 270.6 m^3 (DWA, 2011&DWS, 2015). Results from the current study compared the water demand per day and per year in Ha-Lambani Village with the values for South Africa at national level and international standard to determine the water demand situation in Ha-Lambani Village. This aspect on groundwater abstraction and consumption has been addressed by objective two of current study and results on such objective are presented and discussed in chapter four.

The absence of systematic data on groundwater demand and use as one of the major problem in managing water resources has already been reported (Molden, 2007; Healy 2010; Brown & Matlock, 2011). For example, Vorosmarty et al. (2005) support the widely cited threshold of the Falkenmark indicator and hesitate to recommend using the model by Yang et al. (2003)

which does not include information on groundwater due to lack of systematic data. The current study aimed to contribute this aspect by proving the methodology on how to systematically generate data on groundwater in unmetered rural areas using Ha-Lambani Village as a case study to inform design appropriate plan for good local governance and management of groundwater resources especially during drought (vulnerability context). This aspect on how to generate data on groundwater abstraction and consumption has been addressed by objective two of current study and results on such objective are presented and discussed in chapter four. However, the procedure followed may require refinement.

The emerging methods for estimating water availability, demand and use argue that the former approaches were based on fixed human water requirements and national scale orientated thereby neglecting the local scale i.e. the catchment level in households (Rijsberman, 2006). Therefore, water resources indices were developed which considered catchment parameters in their computations. For example, Raskin et al. (1997) developed water resources vulnerability index also known as WTA ratio. These indices are ratios of total annual withdrawals for human use to available (renewable) water resources at household in the catchment. The country is considered water scarce if withdrawals are between 20% and 40% of annual water supply (Alcamo et al., 2000). For instance, the index of local relative water use which is used to assess the availability of freshwater in a particular catchment, its computation equals the water use in each segment of a catchment or area divide by the river corridor discharge. In the current study, the study area was Ha-Lambani Village which has several clusters and compounds. Six compounds were selected for the purpose of this study.

The definitions of water use exist but the current study uses the definition of Vorosmarty et al. (2005) who states that water use refers to total water withdrawals for domestic (D), industrial (I) and agricultural (A) sectors. A watershed sustainability index for water use was developed by Chavez & Alipaz (2007) who suggested hydrology, environment, life and policy as parameters for their model. McNulty et al. (2010) developed the water supply stress model to quantitatively assess the relative availability of water supply and demand at watershed level. The model is similar to WTA ratio by Raskin et al. (1997). The use of both models depends on availability of information specific to river catchments which are scarce in many regions (Brown & Matlock, 2011) hence the limitation to apply such models. This justifies the assumption for the current study to provide a method of generating data on water demand and use at sub-catchment level focusing on a small area, the Ha-Lambani Village as a case study which can be used in such models especially in unmetered rural areas.

The International Water Management Institute (IWMI) used the similar water scarcity assessment approach as described in the preceding paragraph but focused on the global scale. The IWMI (2008) assessment considered the portion of renewable freshwater resources available for human requirements with respect to the main supply. Globally, countries were divided into two categories: i) physically water scarce and ii) economically water scarce (IWMI, 2008). The physically water scarce countries refer to a situation when 75% of river flows in that area are withdrawn for agriculture, industry and domestic purposes. Molden (2007) highlights indicators for physically water scarce situation as environmental degradation, diminishing groundwater levels and water allocations that support some sectors over others. Ha-Lambani village in South Africa falls in the category of physically water scarce situation as described in several documents including (DWA 2011& DWS, 2015). However, economically water scarce countries refer to countries that have adequate renewable water resources with less than 25% of water from rivers withdrawn for human purposes, but they lack improvements in existing water infrastructure to make such resources available for human use (Molden, 2007; IWMI, 2008; Brown & Matlock, 2011).

The main research problem being addressed in this study is the lack of systematic data to inform appropriate implementation plan for local groundwater good governance in rural unmetered areas during drought. Therefore, investigating factors that need to be understood to explain the availability and governance of water resource for effective management of such resources is essential. Although the average annual rainfall estimates are below the average global figures, the presence of oceans around South Africa, suggests that the country also suffers from the economically water scarce problem. Nevertheless, various sources show that South Africa is physically water scarcity country (DWA, 2015, DWS, 2016). This informed the current study to use the capability approach, resilience approach and sustainable livelihoods approach collaboratively as a theoretical framework in order to understand what people do during drought events; what they do adapt to such events and what they do to sustain their livelihoods. GWP (2000) emphatically stated that since water sustains all life, effective management of water resources demands a holistic approach that links social and economic development with the protection of natural ecosystems. Hence, using a combined approach to provide explanation on people's capability, resilience and livelihoods strategies to sustain them during drought events was envisaged fundamental. The observed limited application of this approach informed the current study to assess domestic water demand, use and its governance during drought in rural communities as a basis to inform designing sustained community-based initiatives.

The methodologies described in the above paragraphs aim at providing estimates on availability, demand and use of water resources. However, no one method seems to be adequate for estimating water availability, demand and use hence, the need for alternative approaches. The initial water availability threshold of between 1,000m^3 and 1,700 m^3 per capita per year developed by Falkenmark in 1989 was an important foundation on which water consumption demands were built. Recognising that water consumption varies among social sectors due to climate variability, technological use and cultural variables led Gleick & Falkenmark (1996) to further develop the water demand threshold of 50 litres per person per day which was adopted by the World bank as a standard threshold providing a yardstick for countries. The selected variables in six compounds of Ha-Lambani Village as described in chapter 4 were used to assess determinants of water demand and use in the study area. This aspect on assessing determinants of water demand and use has been addressed by objective three of current study and results on such objective are presented and discussed in chapter four where statistical modelling approach using regression modelling issued.

The observed continued increase in domestic water withdrawals with the associated increase in water consumption led to recognising the importance of assessing water flows necessary for ecological quality and sustainability (Sullivan, 2002, Asheen, 2003; Vorosmarty et al., 2005; Chaves & Alipaz, 2007; Pfister et al., 2009). To measure water availability, demand and use in a holistic manner including all the socio-economic, ecological and industrial factors, Hoekstra et al. (2003) suggested the water footprint method. However, Ridoutt et al. (2009) cautioned that the water footprint method needs to be improved first before using it so that a standardized model is created to allow comparisons between areas, products and other parameters. This situation explains the on-going search for methods that can be used to generate data and estimate water availability, demand and use in a more agreeable manner. The first step is to provide a method on how to generate data for such methods which is the thesis for the current study because such estimates require measured or observed data which can then be used in modelling processes and the provided method can be refined with time. This study narrows such gap by recommending a method (indirect method) and demonstrating a procedure on how data on groundwater can be generated in rural unmetered areas, using Ha-Lambani Village in Limpopo Province of South Africa as a case study.

The review presented in this section 2.4 has shown that the need for alternative methods exists that would measure the availability, demand and use of water resources. However, the procedure to generate such measured data is not provided in the above methodologies. The current study aimed at providing that procedure to produce measured data that can be used in such models including informing practical action plan on enforcing good governance in managing water resources especially local groundwater resource in the context of drought. Despite the uncertainties associated with scientific methods in general and with the proposed method on generating data on water availability, demand and use in the current study, the systematic procedure provided is a major step towards a more informed procedural assessment approach on data generation. The implication of such approach to inform the designing of appropriate implementation plan that ensures enforcement of good governance practices in managing water resources especially groundwater in the vulnerability context of drought in rural unmetered areas is fundamental and requires sustained nurturing.

2.5 Water governance from vulnerability context of drought event

2.5.1 Water governance: The origin and relevance to scientists/researchers

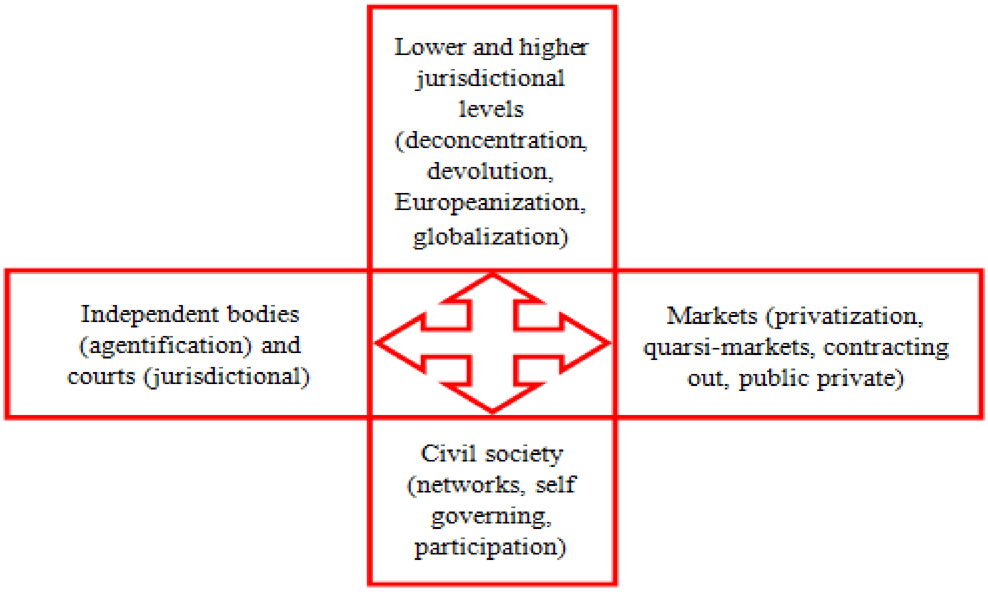


Figure 1: The origin and relevance of water governance to scientist/researchers

The term governance started in 1990s due to implementation of neo-liberal policies which weakened the regulatory powers of nation states (Swyngedouw, 2005) because of the financial crises of the 1980s and 1990s. The result was the shift towards the market-oriented rule and new public management. In essence power and authority from the nation state has been transferred to markets, to civil society, to independent bodies and the courts, and to both higher and lower jurisdictional levels (Huitema, 2005) as shown in Fig 1 above.

Huitema and Meijerink (2009) report that some of these shifts in governance have also occurred in the water sector in terms of policy changes (transitions) where many countries have moved towards greater levels of market involvement (privatization of water services), greater levels of civil society involvement (water user associations, more public participation), and more independent bodies (such as river basin committees). There is also a clear movement towards greater levels of international involvement, with the number of transboundary water agreements increasing, and the growing influence of organizations like the European Union, World Bank and Asian Development Bank.

What attracts scientists to the term "governance" is its ability to "cover the whole range of institutions and relationships involved in the process of governing" (Pierre and Peters 2000). Clearly, "governance" is not the same as government. While government centres on the institutions and actions of the state, the term governance allows non-state actors such as businesses and civil society to be brought into an analysis of societal steering. When we study governance, we are interested in "the totality of interactions, in which the public as well as private actors participate in i) solving societal problems or creating societal opportunities; ii) attending to the institutions as contexts for these governing interactions; and iii) establishing a normative foundation for all those activities". In applying the term governance as defined in this section 2.5.1, it means we are interested in the efforts by private and public actors to steer, control, or manage water resources but we are interested in the institutions that are ready to take up this task, and the normative underpinnings of these efforts and institutions. Therefore, the present study seeks to explore appropriate implementation plan for effective local groundwater governance using Ostrom design principles of good governance for domestic water demand and use. Details on the application of the eight Ostrom designed principles are provided in section 2.5.2 in line with evidence from the scholarly work.

2.5.2 The role of Ostrom design principles in water governance

The first design principle of Ostrom on **well-defined boundaries** around resource system in communities was applicable in many areas (Agrawal, 2002). Pinkerton and Weinstein (1995) found that exclusion of outsiders from fishing space was the main mechanism used by the villagers to control fishing effort. This is one of the most common and universal mechanisms found in community-managed inshore fisheries. This principle is rigid because in many systems, fuzzier social or geographic boundaries are needed to facilitate more flexible, ad hoc arrangements between participants (Ruddle 1996, Turner 1999, Cleaver 1999, 2000, Mandondo 2001, Blaikie 2006). Cleaver (1999) states that a focus on boundaries highlights the need in developing clear administrative arrangements, more to do with the delivery of goods and facilities than a reflection of any social arrangement. In agreement, Turner (1999) observes that practitioners tend to expect the communities to be an immutable group of people jointly managing a delimited common resource through uncontested, clearly defined rules of access.

Principle 2 on **congruence between appropriation and provision rules and local conditions** refers to two aspects per Agrawal (2002) understanding, recognised local condition to mean spatial and temporal heterogeneity in that appropriation and provision rules conform in some way to local conditions; and that congruence exists between appropriation and provision rules. Very strong empirical evidence exists in literature for both aspects of this principle. Most literature reflects Ostrom's emphasis on an institutional congruence with the resource condition as shown in the case studies of the Spanish irrigation and Peruvian irrigation systems (Guillet, 1992). Local conditions can also refer to involving the predominant culture, ideology, customs, and livelihood strategies of a community (Morrow & Hull, 1996; Young, 2002; Gautam & Shivakoti, 2005). The negative effects of imposing external rules do not match local customs and livelihood strategies. For example, Gautam and Shivakoti (2005) observed that the rules designed by the Dhulikhel municipality imposed a total ban on the harvest of forest products and that these rules did not match the resource conditions and contradicted customary rules of villagers, who had traditionally allowed activities such as the collection of leaf litter for animal bedding and fallen twigs for firewood. In turn, the effectiveness of monitoring and compliance with rules was very low, and the forest had come under high extraction pressure. Morrow and Hull (1996) studied a donor-initiated forestry cooperative in the Palcazu Valley of Peru and came to similar conclusions regarding the need for this internal-external type of congruency.

Congruence between appropriation and provision rules is frequently described in the literature as congruence between costs incurred by users and the benefits they receive via their participation in collective action. Pomeroy et al. (2001) agreeing with Ostrom's finding, report that in successful systems, "individuals have an expectation that the benefits to be derived from participation in and compliance with community-based management will exceed the costs of investments in such activities." Similarly, Klooster (2000) compared seven communities that have been successful in managing logging activities and found that a common feature in these communities is their effort to fairly reinvest benefits into the community by paying for reforestation work and providing public goods.

Principle 3 on **collective-choice arrangements** states that most individuals affected by the operational rules can participate in modifying the operational rules. Most scholarly work highlights the importance of local knowledge in natural resource management. For example, Berkes et al. (2000) report that local users have first-hand and low-cost access to information about their situation have a comparative advantage in devising effective rules and strategies for that location, particularly when local conditions change. Case studies on Nishikanbara Land Improvement District in Japan Sarker and Itoh (2001) and managing communal grazing land in rural Tanzania (Nilsson, 2001) among others have demonstrated the application of this principle. However, Cleaver (1999) and Skjølsvold (2008) caution about the role of locally powerful or external bureaucratic actors who in practice are co-opted or undermine the role of communities by bring in the administrative or bureaucratic imposition or ignore some important features of the local context.

Principle 4 on **monitoring** stipulates the presence of monitors and the condition that these monitors are members of the community or otherwise accountable to those members. Monitoring makes those who do not comply with rules visible to the community, which facilitates the effectiveness of rule enforcement mechanisms and informs strategic and contingent behavior of those who do comply with rules. Various studies support the application of this principle. For example, monitoring is a by-product of particular ways of managing the commons, and the costs of monitoring are kept low (Schmidtz & Willott 2003). Trawick (2001) and Cox (2010) show how community irrigation system in Peru and New Mexico respectively became effective at conserving water and facilitated effective decentralized monitoring. Bardhan (2000) performed a statistical analysis of 48 irrigation systems and found a positive correlation between cooperative behavior and the presence of a guard position concluding that villagers are more likely to hire guards and impose fines more frequently if their forests are not in a good condition in an effort to improve their forests.

Principle 5 on **graduated sanctions** stipulates the efficacy of graduated sanctioning systems. Sanctioning deters participants from excessive violations of community rules. Graduated sanctions progress incrementally based on either the severity or the repetition of violations. Graduated sanctions help to maintain community cohesion while genuinely punishing severe cases; they also maintain proportionality between the severity of violations and sanctions, similar to the proportionality between appropriation and provision rules from principle 2. Ghate and Nagendra (2005) show the failure of efficacious forest management in two communities in Maharashtra, India, relative to successful management in a third. Although graduated sanctions formally existed in all three communities, only the successful community had a strictly implemented, graduated penalty structure. However, some scholars argue that sanctions are not needed in the presence of strong social capital and should not be implemented as a replacement for it. The design principle abstracts too much from local context (Cleaver, 2000). In most cases people prefer to spend more time negotiating consensus than establishing and imposing sanctions with regards to mechanisms of water resource management. Cleaver (2000) concluded that villages are most successful at collective action regarding water supplies.

Principle 6 on **conflict resolution mechanisms** states that systems with low-cost conflict resolution mechanisms are more likely to survive. Conflict over an exhaustible resource is inevitable in CPR management, necessitating the presence of established mechanisms for conflict resolution to maintain collective action. This principle was moderately well supported by the empirical data (Cox, 2010).

Principle 7 on **minimum recognition of rights** stipulates that external government agencies do not challenge the right of local users to create their own institutions. An external government agency imposing its own rules on a community managing a CPR may suffer from a government failure of the kind discussed by Hayek (1945) and Scott (1998) if the externally imposed rules do not correspond to local conditions. The empirical evidence for this principle exists. For example, Pagdee et al. (2006) in their analysis of 69 case studies of forest management worldwide found that local authority local knowledge and existing institutions was associated with tenure security, a key element for sustainable forest management (Turner, 1999).

Principle 8 on **nested enterprises** states that in successful systems, "governance activities are organized in multiple layers of nested enterprises" (Ostrom, 1990). As for principle 7, which also deals with cross-scale institutional factors, the empirical evidence for principle 8 was moderately supportive. Many scholars, particularly those focusing on pastoral and irrigation systems, have stressed the importance of nesting smaller common-property systems in larger and still larger ones, given the high probability that the social systems have cross-scale physical relationships when they manage different parts of a larger resource system and thus may need mechanisms to facilitate cross-scale cooperation (Lane & Scoones, 1993; Niamir-Fuller, 1998). Hanna et al. (1995) reported that the nesting may occur either between user groups and larger governmental jurisdictions, or between user groups themselves including horizontal and vertical linkages because they may accomplish similar functions.

2.5. 3 Groundwater governance in context of drought (vulnerability context)

The concept of groundwater governance has emerged recently in the groundwater community (Wijnen et al., 2012). The concept is understood as "an overarching framework and set of guiding principles that determines and enables the sustainable management of groundwater resources and the use of aquifers". The lack of adequate governance – i.e.:overarching enabling frameworks and guiding principles–hinders the achievement of groundwater resources management goals such as resource sustainability, water security, economic development, equitable access to benefits from water and conservation of ecosystems. The present study focuses on water security i.e. the water demand and use during drought events.Governance is a complex concept, which is reflected in the fuzzy and often rather long definitions produced by a variety of authors. A comparatively concise definition of governance is presented by Wijnen et al. (2012) who state that governance is understood as the operation of rules, instruments and organizations that can align stakeholder behaviour and actual outcomes with policy objectives. Sanier and Meganck (2007) explain that groundwater governance is the process by which groundwater is managed through the application of responsibility, participation, information availability, transparency, custom and rule of law. It is the art of coordinating administrative actions and decision making between and among different jurisdictional levels – one of which may be global.

The specific elements of governance as mentioned by the definition of Sanier and Meganck (2007) are value-laden terms that define "good governance" as opposed to just "governance". These qualities may be the views and preferences of some actors, but not necessarily all. Foster and Garduño (2013), understand the term „governance" to mean the exercise of political, economic and administrative authority of national affairs at all levels – and comprises the mechanisms, processes and institutions through which citizens articulate their interests, mediate their differences and fulfill their legal rights and obligations. Consequently, Foster and Garduño (2013) conclude that groundwater governance comprises the promotion of responsible collective action to ensure socially-sustainable utilisation and effective protection of groundwater resources for the benefit of humankind and dependent ecosystems. In spite of some room for differences in interpretation of these definitions, it may be concluded that they characterise groundwater governance as being process-oriented rather than action-oriented and hence the need to explore appropriate implementation plan for groundwater governance at local scale.

General principles of good groundwater governance – like the governance of all other natural resources - are included in the above-mentioned definition by Sanier and Meganck (2007): the application of responsibility, participation, information availability, transparency, custom and rule of law. A number of important aspects and considerations in this context, subdivided into four categories, are described in the below paragraph. These aspects give an impression of the variety of elements and dimensions attributable to groundwater governance.

Varady et al., (2012) highlighted the important aspects need to be considered in groundwater governance in pursuit for operationalising the principles of good groundwater governance as follows: 1) Political and institutional aspects: accountability, representation, consistency, scalar match, institutional match, institutional capacity to adapt to change and uncertainty; 2) Socio-cultural aspects: perceptions about groundwater, religious and spiritual traditions, social learning, social inclusion, ethics, multi-level/ multi-scale/polycentric, governance models; 3) Economics aspects: imperfection of price, signals (market failures),role of water scarcity and groundwater storage, water quality impacts, inadequate water use and monitoring, role of private sector, role of public-private partnerships, ability to pay and external costs; 4) Ecological aspects: Diffusivity and conduciveness, attenuation rates, renewability, vulnerability, provisioning versus ecosystem services. The present study attempted to include some aspects of the elements of groundwater governance as presented by Sanier and Meganck (2007); Varady et al., (2012); and Foster and Garduño (2013) in designing an appropriate implementation plan for local groundwater governance as presented and discussed in Chapter 5 on rural domestic water governance.

Since groundwater is a "common-pool resource", groundwater governance is likely to benefit from an application of design principles defined by Elinor Ostrom for developing institutional arrangements for the management of such resources (Foster & Garduño, 2013) summarised as follws:1) Clearly defined boundaries for resource evaluation and allocation; 2) Congruence between proposed resource allocation and prevailing natural constraints; 3) Formal recognition of the rights of the local communities to organise resource use; 4) Collective arrangements for the participation of stakeholders in decision-making; 5) Nested stakeholder groups to cope with geographically large resource systems; 6) Effective independent monitoring of resource status; 7) Graduates sanctions on resource users or polluters who do not respect community rules; 8) Mechanisms for conflict-resolution that are accessible, rapid and inexpensive. The present study tested the application of these principles in Ha-Lambani village and provided analytical comments on aspects that applied and not applied.

There are no general valid blueprints for dealing with all these aspects or applying all the aforementioned "good governance principles" as Elinor Ostrom wrote: "context matters". This implies that the adoption of widely embraced "good governance" paradigms such as sustainability, market approaches and decentralisation need to be critically viewed in the particular context of each case. The present study in Ha-Lambani Village is no exception with the notion of Elinor Ostrom who encourages considering the context of the study area when applying principles of good governance. The context of the present study is vulnerability context of drought, adding a layer to Ha-Lambani Village which is in semi-arid region, water scarcity situation of South Africa and in rural areas where water sources are unmetered. Finally, it needs to be emphasized that "good governance" and "effective governance" are two different concepts. Groundwater governance is effective if the goals set out by the government are being met. Governance is good if countries attempt to reach these goals in a way that incorporates "good governance principles" as outlined above. The implementation plan being explored in the present study aims at considering some of the aspects of good governance in groundwater at local to meet the demand and use by people.

2.6 Theoretical and conceptual framework

Section 2.6 presents the reviewed literature on the theories, concepts and approaches that inform the current study on domestic water demand, use and its governance in rural areas during drought. These theories provide assumptions and principles in their original and modified versions over time by various scholars in different contexts. The section 2.6 describes them and explains why and how such theories are used in the current study.

2.6.1 Capability theory

The present study uses the Capability Approach (CA) as the theoretical framework for the study. This approach is used to interpret the data. In its origin, the capability approach is used as an economic framework that assesses poverty and human development using equalities in society as indicator (Clark, 2005). In addition, Goldin (2013) from her anthropological background argues that the CA provides a guide to help conceptualize and evaluate poverty-related phenomena in societies. The central message in the capability CA is about what people are able to do (opportunity) or capable of doing. This notion guides the research questions for this study. Importantly, it helps answer the question what are people able to do to positively adapt to adverse events of droughts? The second theoretical concept that we deploy in this study is the concept of resilience. Resilience refers to people's ability to successfully adapt to life tasks during adverse conditions/events. Pecillo (2016) in his review of the resilience concept states that resilient people have, through time, developed proper coping techniques that allow them to effectively and relatively easily move around and through crisis. The present study explores what people are capable of doing to enable them to adapt, and even to thrive, during adverse events of drought and it uses the Ha-Lambani Village as its site of investigation.

2.6.2 Resilience theory

The current study uses the concept resilience as the conceptual model (theme) for the study. The term resilience has been defined by various authors in different context. For example, Perrings (2006) defines resilience as the ability of the system to withstand environmental shocks without losing the capacity to allocate resources efficiently while Fleming & Ledogar (2010) define resilience as positive adaptation despite the prevailing hard times. Resilience can reflect the ability of a system to become used or become accustomed to change, but also the ability of a system to persevere despite the exiting hardships at a particular times (Gunderson &Light, 2006 & Keessen et al., 2013). Southwick (2014) defines resilience as a process of acclimatizing oneself to adverse conditions while Pecillo (2016) defines resilience as people's ability to a successfully adapt to life task during adverse events. Although the review from the above scholars offer the same meaning about the definition of the concept of resilience, the definition offered by Pecillo (2016) and Fleming & Ledogar (2010) informs the operation understanding of the concept of resilience for the current study which aligns well with the research question of this study which seeks to answer "What do people do during prevailing hard times such as drought to adapt positively? The hypothesis of the present study is unless what people do when they face hardships during droughts is known or investigated, any intervention designed for such people will not be long lasting for them. Alternatively, the present study argues that it is important to investigate people's ability to a successfully adapt to adverse events such drought and Ha-Lambani Village is used a case study to answer such a research question.

2.6.3 Sustainable livelihood approach

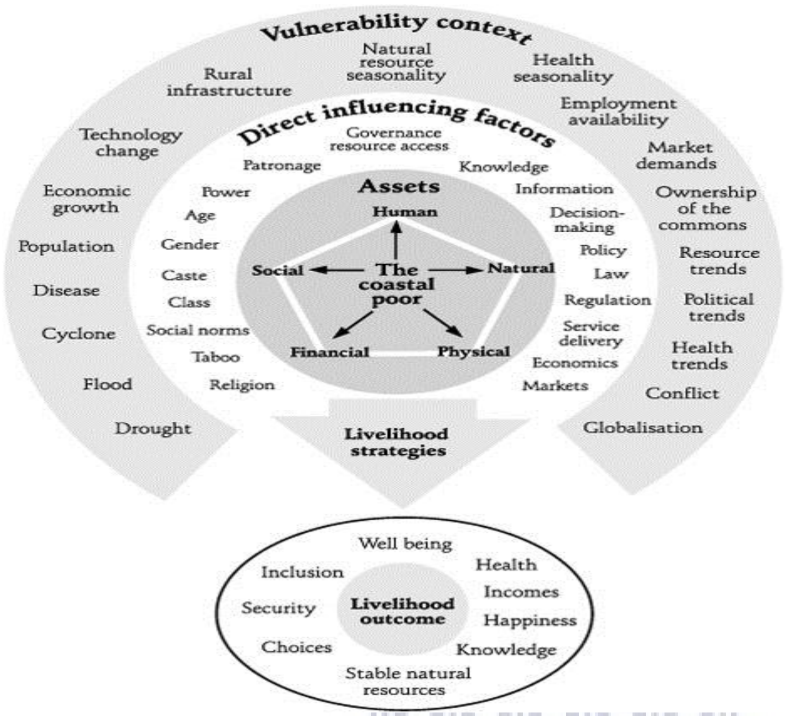


Figure 2: Sustainable livelihoods approach (SLA)

The Sustainable Livelihoods approach (SLA) has been explained and expanded upon by several authors (Carney, 2000; Ashley, 2000; Baumann 2000; Scoones 1998; Ellis, 1999). Therefore, many details on the approach are left out in the present study. However, a brief synopsis of the main principles underlying SLA and aspects of the SLA framework are shown in Fig. 2, where selected aspects of the SLA framework that apply to the present study are discussed in the theory application of chapter 5 of this thesis. Such aspects include vulnerability context (drought), influencing factors (resource access), assets (water as natural assets), strategies (research question) and livelihoods outcome (water security) among others.

The present study agrees with FAO's use of the SLA where the aim is to foster local institutions for improving rural livelihoods and ensuring equitable access to resources such as water demand and use in the current study. In addition, it strengthens links of local institutions to appropriate local municipality and district municipality to regional and national institutions (Bennette, 2010). SLA application aims at building capacity of local institutions and empowering local populations through their participation in governing and managing their water resources especially during drought events. Livelihood is sustainable when it can enable people to cope with and recover from adverse effects of events; maintain and enhance people's capabilities as natural resources water resource are protected (Scoones,1998).

Baumann (2000) examines the use of SLA in two districts in India, Dehradun (Uttar Pradesh) and Rayagada (Orissa) to show the need for SLA in incorporating political capital as an endogenous asset within the livelihoods framework. This resulted in changing local power structures opposing the local elites. This built up resistance when there were attempts to organise the local population into groups for changing local access to resources. Based on the lesson from India's study, the present study excluded the political assets in the study.

The use of SLA in the present study aims at understanding livelihood strategies (What do people do during drought?) that enhance the community-based natural resource management practices. The focus is to build local institutional capacity for governing the water resources especially during drought events. The discussion of the results on application of the SLA is based on some lessons from other studies on the practical use of SLA. One of the motivation for the use of the SLA is that the framework is not used in isolation but bring together different perspectives for contributing to a people-centred approach and SLA is used as a tool to designing intervention (Ashley & Hussein, 2000; Baumann, 2000; Manzetti, 2001). In the present study the SLA is used alongside the capability and resilience approaches in pursuit to answer the research question what do people do to adapt or sustain their water demand and use livelihoods with the aim of designing an implementation framework that ensures local governance intervention of groundwater resources during drought events in rural areas.

The current study employs the SLA by examining the components of the SLA framework that are applicable in the study. The aim is to demonstrate an understanding of the how the vulnerability context (drought); prevailing factors (knowledge, service delivery, governance, rescue access); existing assets (human, physical and natural) that influence people in the study area to do what they do to adapt to drought or to sustain them during drought (coping strategies). The research question is what do people do during drought to sustain their livelihoods? To answer such question, water demand and use are assessed and factors that influence such demand and use are determined. Such assessment provides a basis to design a mechanism to ensure that the outcomes of people's livelihoods are sustainable (De Haan, 2012). Discussions of these aspects are presented in chapters 4, 5 and 6 of the present study.

2.7 Conceptualized analytical model of the research problem

The flow diagram presented below is a conceptualized analytical model of the research problem for this study. It bridges the theory to analysis. It helps to see whether or not the research questions are answered. It has helped to guide and structure the analysis in this study. The model shows how water demand and use assessment inform the basis for demonstrating the appropriate implementation plan for effective local groundwater governance practice and showcasing the application of theories on how people adapt to drought events in rural areas. The model has three categories: a) water demand and use (i.e. determination and factors that influence such demand and use); b) implementation plan for effective local groundwater governance and c) application of approaches for the study. The conceptualized end results from each category or each objective are shown in the model below and as well as in the research design table in section 3.2 of chapter3

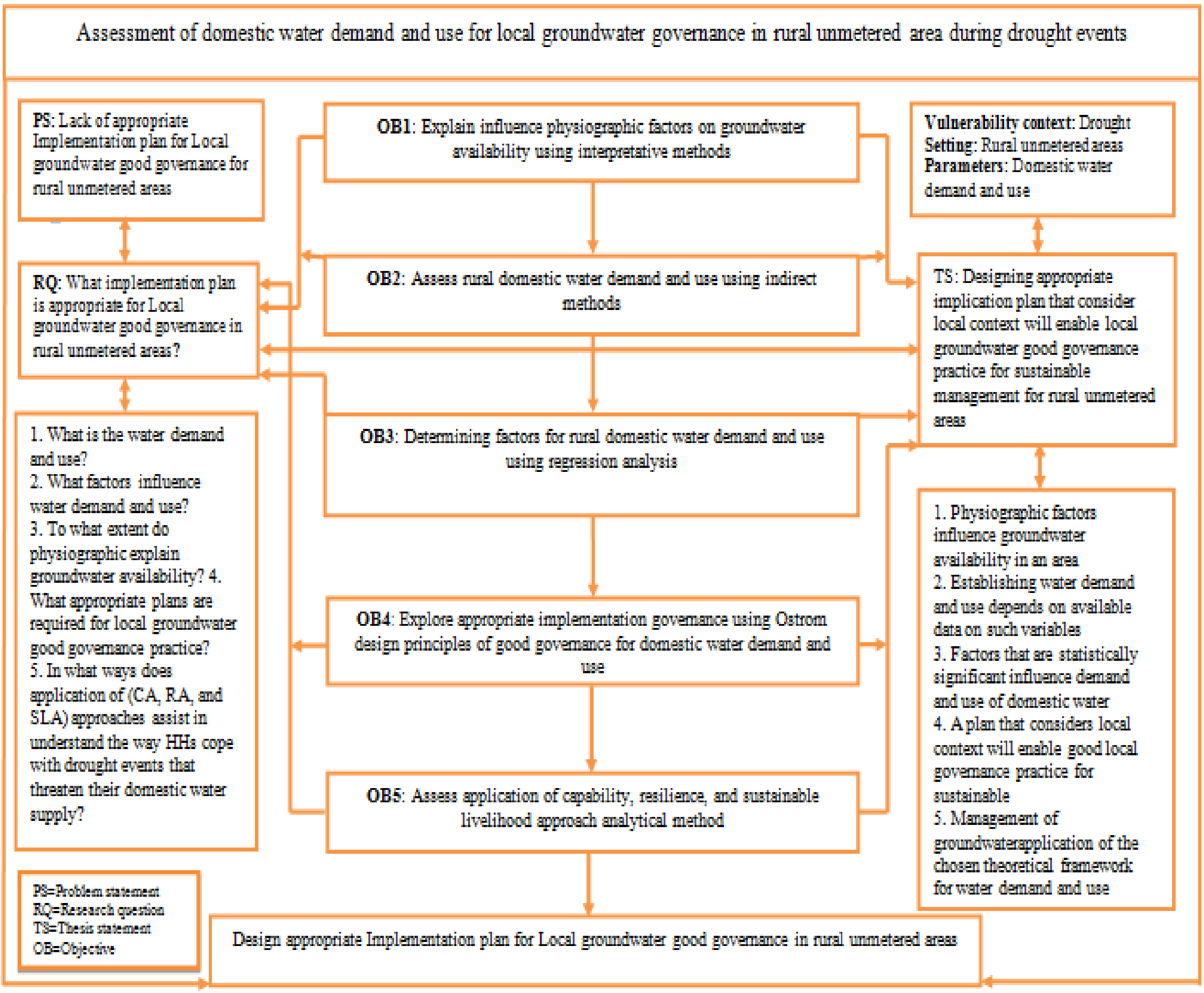


Figure 3: Conceptualised analytical model of the research problem

2.8 Chapter summary

This section has described the overview on water resources globally and in South Africa in the context of vulnerability due to climate change effects. The effects of climate change on water resources have been shown. Further, theories that are envisaged relevant to the present study have been described in context of the drought situation. The need for implementation plan that would ensure effective governance and management of groundwater resources at local level (community/village level) has been highlighted. The need to use capability, residence and sustainable livelihoods approaches as theoretical frameworks in comprehensive understating of how people adapt to extreme events in rural communities has been described. The discussion of the empirical results will be along such reviewed literature in answering the research questions. The analysis will focus on local scale (village level, that is Ha-Lambani Village) because usually the effects of drought events are realized more at local level. The analytical approach formulated within the vulnerability context bridges the introductory and literature review chapters to analysis chapters via methodology. The thrust of the thesis is based on the notion that we need first to establish the availability, demand (abstraction) and use of the available water first in any study area then explore appropriate implementation plan to ensure effective local groundwater governance practices in communities. Therefore, applying capability, resilient and sustainable livelihoods approaches from multi-method perspective in vulnerability context helps to provide a better understating on how people cope with effects of extreme events such as drought especially in unmetered rural areas.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

Chapter one has provided the situational analysis that informed the problem statement, research question, the main thesis statement, aim, scope, rationale and objectives of the current study whereas chapter 2 has presented the reviewed literature on the what is known and not known with regards to the current study topic in addition to the theoretical and conceptual framework that inform the present study. The current chapter describes the research design, research methodology and research methods that were used to collect and analyse the needed data to answer the research question set in chapter one thereby fulfilling the objectives for present study. In this chapter, the argument is that detailed description on i) research design; ii) research methodology; iii) research methods for data collection and analysis and iv) statements on research integrity are important because they provide the basis for the results of the present study to be considered adequate, objective and appropriate evidence for answering the research question of the current study.

3.2 General study approach and research design table

3.2.1 Case study approach: The Ha-Lambani Village

The general approach to this study was a case study approach whereby Ha-Lambani Village in Thulamela local Municipality of Vhembe District in Limpopo Province of South Africa was used as a case study. A comprehensive approach to understanding procedure of generating data on water demand and use in unmetered rural areas and factors that influence water availability, demand and use was adopted. The focus was to show procedure on how to generate data on water demand and use, explain factors that influence such demand and use, demonstrate the design of implementation framework for local groundwater governance practice and illustrate application of theoretical and conceptual frameworks used for the present study from vulnerability context of drought events. The following procedures were followed:i)carriedoutdeskstudyassessment(literaturestage);ii)refinedresearchproposal iii) selected appropriate research design; iv) conducted fieldwork activities and v) analysed data for discussion to answer the research question based on the study research problem.

First, a desktop study was conducted on water demand and use with focus on groundwater governance. The literature review focused on domestic water demand and use during drought events in relation to groundwater governance in South Africa, SADC region, Africa and the world. Literature showed progress and gap analysis on local groundwater governance and groundwater management as presented in chapters 2. Wentzel (2009) argues for fieldwork measurements because desktop studies provide low intensity information requirements which give low confidence. Nevertheless, desktop studies form the first step i) in planning informative research process and ii) in setting a clear theoretical framework (capability, resilient and sustainability livelihoods approaches) of the study as shown in chapters 2.

The proposal was prepared and presented to supervisory committee of the University of the Western Cape (UWC) which approved the research design, research methods and the planned methodology of the current research project as presented in 3.4. The detailed design of this research is presented in section 3.3. Fieldwork activities and data analyses are presented in section 4.5. The details on alignment of research objectives, research question, research methods and expected results are presented in research design table 3.2. However, each result chapter (4.1, 5.1 and 6.1) carries a section on methods to elaborate analytical procedure and to contextualize the discussion in that chapter.

3.2.2 Research design table showing alignment of general study approach

Table 1:Research design table showing alignment of general study approach

Research objectives	Research question	Research hypothesis	Research methods	Expected results
Explain the influence of physiographic factors on groundwater availability	To what extent do physical factors explain groundwater availability	Physiographic factors influence groundwater availability in an Area	Field observation and record review Interpretative methods Analytical method	Qualitative assessment on key insights on how physiographic factors explain groundwater availability in an area
Establish rural domestic water demand and use	What is the water demand and use?	Establishing water demand and use depends on available data on such variables	Interview and field observations Indirect quantitative methods of analysis	Amount of water abstracted (demand) from the source, used and unused at HH and village/area level
Determine factors for rural domestic water demand and use	What factors influence water demand and use?	Factors that are statistically significant influence demand and use of domestic water	Interview and field observations Multiple regression analysis	Statistically significant factors that influence demand and use of domestic water
Assess appropriate plan of implementing local groundwater good governance practice	What appropriate plans are required for local groundwater good governance practice?	A plan that considers local context will enable good local governance practice for sustainable management of groundwater	Records review and on different plans of implementation Interpretative methods Analytical method	Establishment of appropriate plan of implementing local water governance practice
Demonstrate application of theoretical framework for water demand and use CA=Capability Approach RA=Resilience Approach SLA=Sustainable Livelihoods Approach HHs =Household	How does the application of (CA, RA, SLA) approaches assist in understand the way HHs cope with drought events that threaten their domestic water supply?	Demonstrating the application of the chosen theoretical framework for water demand and use provides the basis for establishing what people do to adapt to effects of drought events in their context	Review case studies on drought events FGD and KII Interpretative methods Analytical method	Showcasing the application of theoretical framework for water demand and use (CA, RA,SLA)

The research design table (Table 1) shows how the research question, research hypothesis, research methods and expected outcome/output for each study objective relate to the main research question, research hypothesis, methodology, and problem statement to achieve study aim.

3.3 Research design

The present study followed the empirical research design which considered both primary and secondary data analysis techniques (Babbie & Mouton, 2009). The methodology and research methods are presented in section 3.4 and 3.5 respectively.

3.3.1 Description of the study area (Ha-Lambani Village)

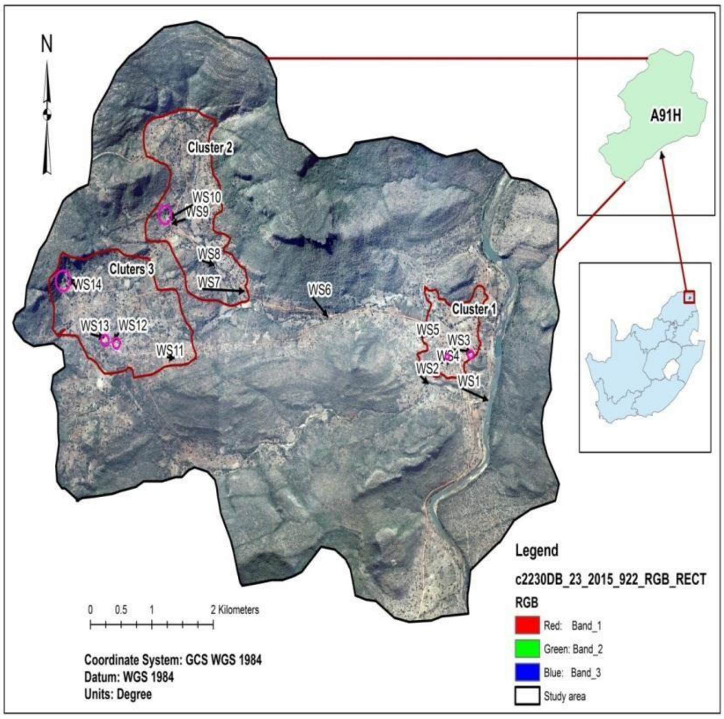


Figure 4: Description of the study area (Ha-Lambani Village)

Ha-Lambani village is located within the coordinates of 22 degrees 42‟59.78"S and 30 degrees 50‟00.01"E about 60 km north of Thohoyandou and approximately 8km south west of Punda Maria Gate (Kruger National Park) in the Limpopo province. It is found under the Thulamela Local Municipality of the Vhembe District municipality in Limpopo in South Africa. This village is bounded by the Kruger National Park from the north-west direction, western side of this it is where Mhinga village found, and Southern part of Lambani is Thohoyandou. The villages next to Ha-lambani include Lamoani (18.7 km), Khavhambe, (24.4 km), Muthati (25 km), Ka-Mhinga (25km), Mavunde (27.5 kam), Hamakuya (29.7 km), Majika (37.3 km) and Phaswane (40.5km) (Botha et al., 2014). These surrounding villages inform the basis for potential collaboration for institutional arrangements to strengthen local governance for groundwater resources through horizontal capital network.

The population in Ha-Lambani was about 3450 with the average household (HH) size of 3.7. Thulamela local Municipality, Vhembe District Municipality and Limpopo Province had average HH size of 3.9, 3.8 and 3.7 respectively. All these HH sizes are much higher when compared to the South Africa national HH size of 2.2 (Stats South Africa, 2014). Ha-

Lambani had 49% of the population being males and 51% were females (Mashego et al., 2010). The population distribution according to age-group was as follows: 37% aged (0-14) is 37. 9%, 58.8% aged (15-64) and 7.8% aged (64+). Such information on HH size, gender and age-group categories had implication on water demand and use in terms of roles and responsibilities with regard to withdrawal, consumption, governing and managing of water.

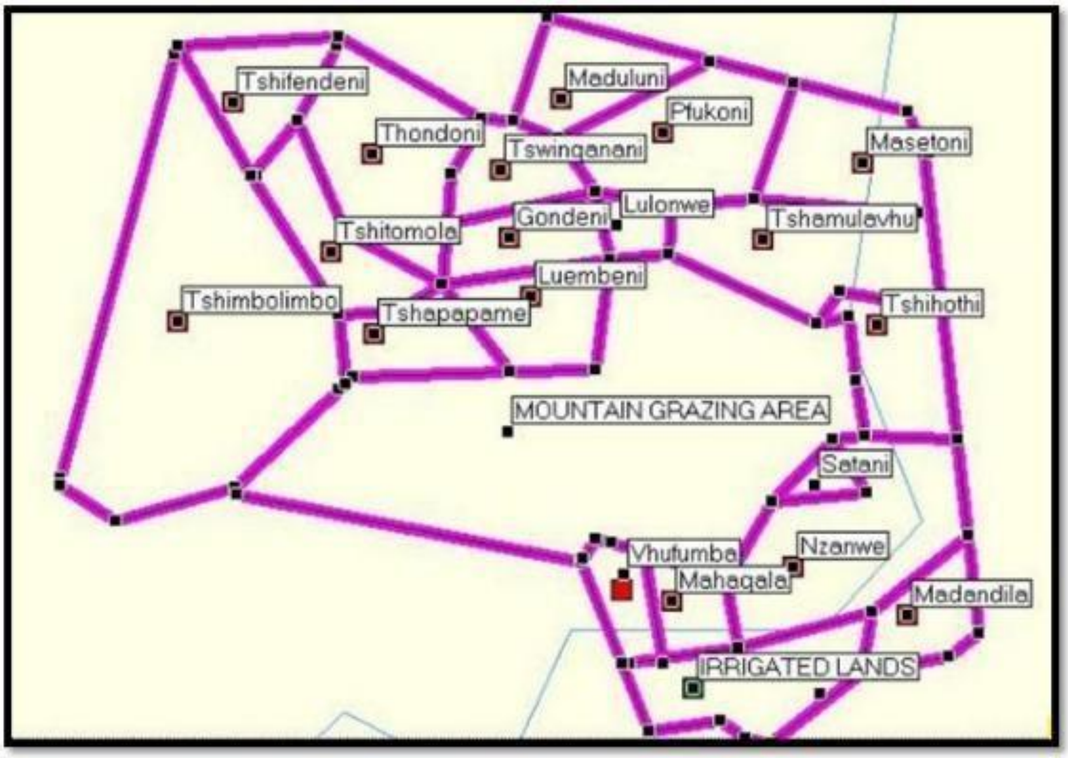


Figure 5: Ha-Lambani Village with its clusters/compounds/sections (Ramugondo, 2014)

Ha-Lambani Village is made up of several clusters/compound/sections as follows: Lulonwe, Pfukoni, Maduluni, Masetoni, Tshamulavhu, and Tshihothi which are closer to Luvuvhu River. The others are Luembeni, Gondeni, Tshapapame, Thondoni, Tshimbolimbo, Tshitomola, Tswinganani and Tshifendeni. Thondoni is the chief compound. Understanding such arrangements provided insights on how institutional arrangement can align the existing compound arrangements for implementation plan of groundwater governance at local scale. The photos below shows some compounds looked like during the field visit.

Figure 6: Examples of types of households found in Ha-Lambani Village (Photo: Lebese, 2014)

Ha-Lambani falls under semi-arid in South Africa which receives a minimum average rainfall of 500 mm and 1000 per annual (Botha, 2014). South Africa is classified as water scarcity country (DWS, 2015). Joseph & Botha (2012) reported that Ha-Lambani village receives most of its rains between October and March. December, January and February are the warmest month an average temperature of 27◦C and July is the coldest month with an average temperature of 19◦C. Ha- Lambani receives average rainfall of 588 mm and with 1395 mm of evaporative demand due to summer couple with high temperature Botha (2014). This means that water availability in Ha-Lambani village is expected to be high during the rainy periods. However, the reduced precipitation in the rainy months (drought) informed the need to design and implement a plan that ensures good governance of the available water that sustain people's livelihood. Hence the aim of the study was to design an implementation plan for local groundwater good governance in order to equip village people with alternative strategies that will help them cope with drought period.

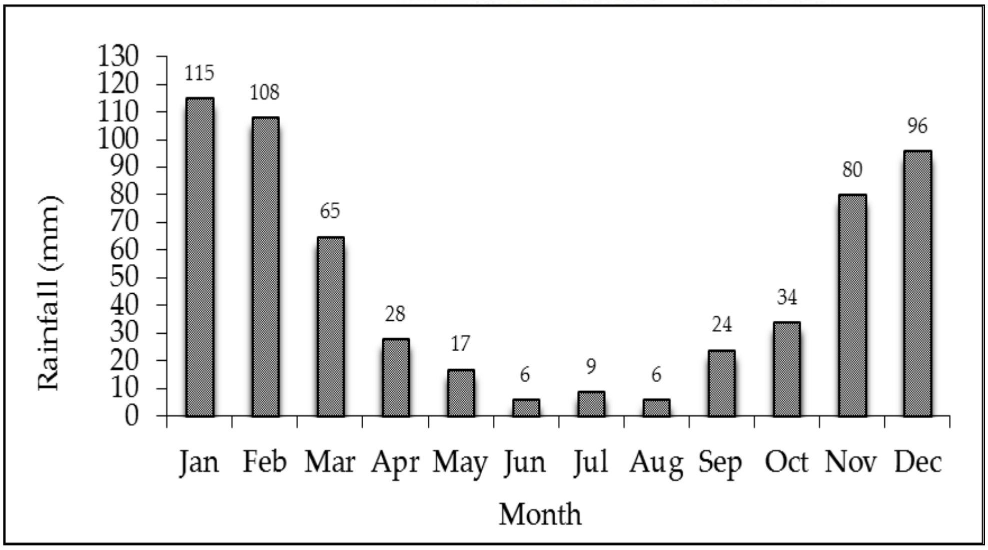


Figure 7: Study Area average rainfall per month (Joseph & Botha, 2012)

Ha-Lambani Village has the Soutpansberg Mountain Bushveld vegetation (Mucina & Rutherford, 2006). This veld type consists of a dense tree layer with a canopy cover of 60-70%, and a poorly developed grassy layer. The plateau areas have open savanna sandveld on both deep and shallow quarzitic sands. Plateau areas are used communal grazing area by the people of Ha-Lambani and neighbouring communities as mentioned in the earlier paragraphs.

There were different sources for domestic water demand and use in Ha-Lambani village. The photos in below paragraphs show some of the sources that were observed during data collection period in the field. Some of the water that comes in Ha-Lambni Village comes from Xikundu weir and such water also goes to Tshifundi Village (DWA,2011).

Figure 8:Xikundu weir (DWA,2011)

The two photos below are examples of boreholes in Ha-Lambani Village which are the sources for domestic water demand and use. It was reported 12 boreholes were not function meaning no water was coming out of those boreholes. These included private and public boreholes. Causes for malfunctioning were not explored in the present study but the situation provides a basis for hydrogeological investigation on boreholes. However, non-working boreholes further reduce sources for domestic water demand and use in the area.

Figure 9:Water sources in Ha-Lambani (Koatla, 2013)

Communal taps or standing taps were other sources for domestic water demand and use in the study. The photos above show some of the communal taps that were observed during filed observation trip in the study area. It can be said that sources of water in Ha-Lambani Villages include: 1) Boreholes; 2) Community taps; 3) Open wells and Luvuhvu River were the main sources for domestic water demand and use in the study village (Photos and map).

3.3.2 Sampling design method

For both qualitative and quantitative data collection, purposive sampling design method was used where households were chosen because they were believed in collecting water from the identified sources. Therefore, it was believed that such households would provide the information that was being sought for the study. Based on such judgemental approach, 92 households were sampled for household's questionnaire and 6 focus group discussions and 5 Key Informant interview (KI) were carried out. In all these data collection tools the themes included: water availability, water demand, water use, local water governance, institution and rules in the context of drought events. Detailed analysis how these were conducted and how data from such instruments were analysed and discussed partly presented in section 3.4 and 3.5 of this chapter and fully presented in chapters 4, 5 and 6 respectively.

3.3.3 Study population

Bobbie & Mouton (2009) state that study population i.e. studied items or study parameters refers to elements such as individuals, objects and events that meet criteria for inclusion in the study. Based on such description, the study populations for the current study were households in relation to water demand and use. Therefore, 92 households were selected for household's survey. The head of the sampled household was interviewed. Where there was no household head, the next household was selected. For key informant interview (KII), elderly people and people with positions in the village were chosen. It was thought that elderly people with long lived-experiences of drought events would provide the needed information on how people adapt to such events. People with positions with their leadership experiences were selected to share with us their experiences on how people adapt to drought.

3.4 Research methodology that was used in the present study

The three main methodological approaches or paradigms or traditions in studies that involve communities are quantitative, qualitative and participatory approaches. The logic or principles or philosophies or thinking underpinning the use of these approaches in studies are different but sometimes compatible. This means that these approaches can be combined or not in one study. In what way chosen, an explanation needs to be provided for the use of either one or more than one approaches in a particular study. For example, the quantitative paradigm is guided by the principles of outsider (unbiased) whereas insider views or live-experiences are articulated in qualitative methodology. The role of actor/agent of change underpins the use participatory methodology where the role of participants is considered essential in initiative or implementing, or evaluating any change in a society (Mouton, 2015). For the present study, methodological pluralism was adopted where by quantitative and qualitative methodologies also known as multi-method or mixed method approach with some elements of participatory approach was used as described in sections below.

3.4.1 The use of multi-method approach in the present study

In the current study, quantitative and qualitative methods were used during data collection and analysis. These methods are called multi-method approach (Brannen, 1992) or triangulation method (Mikkelsen, 1995). Quantitative methods are seen as having some kind ofone-to-onecorrespondencewithpositivistepistemologyaimingatshowingthemagnitude of the issue being studied in order to reach a generalization such as percentages. For qualitative methods, this is different as they are associated with an interpretative epistemology directed towards uncovering meanings of the issue being studied at a deeper level. In-depth analysis of what is being studied is provided for in the qualitative methods (Halfpenny, 1979). Let me repeat here that using both methods in one study offsets the weaknesses of each other hence making findings and analysis more reliable and valid.

Both quantitative and qualitative methods used played an equal part in data collection. The present study was observational in design and was conceived in a multi-method paradigm. It focused on establishing water availability qualitatively, water demand and use quantitatively and then explaining factors that influence water availability (qualitatively) and factors that determine water demand and use (quantitatively). Some variables were predefined in a semi-structured questionnaire. Objectives 1, 2 and 3 on water demand and use, descriptive data and statistical explanations were sought hence the use of quantitative methods. Therefore, a confirmatory analysis was carried out where indirect method was applied, setting a hypothesis were set and regression analysis was used as shown in research design table(3.2).

On objective 4 on local groundwater governance and 5 on application of theoretical framework, a new thought developed which centred on people's constructions and definitions for their experience of vulnerability during drought in rural areas, capability, resilience and sustainable livelihoods during such events (droughts). The focus was on people's experiences of drought events and ways of coping with such situations when they are faced with water shortage in rural areas. Finally how continuous would the planned coping strategies be for their livelihoods when their water supply dwindles and what governance structures are in place to manage such waters. So this made me to use findings from the quantitative methods (indirect methods and regression analysis) to explain the required implementation plan and show how the meanings of capability, resilience and sustainable livelihoods approaches can help in understanding how people cope with extreme events of droughts in vulnerable areas.

Note that Ha-Lambaini Village is in Semi-arid, water scarcity country (South Africa) and unmetered rural areas. In this case exploratory analysis from qualitative methodology was more appropriate for such explanatory and interpretative approach. This was mainly because the study then became more of exploratory in nature (objectives 4 on local groundwater governance and 5 on application of the theoretical frameworks). Therefore, both methods were used. Quantitative methods provided statistical data and qualitative methods provided explanation on the generated statistical data.

3.4.2 The theoretical basis for using multi-method approach in the present study

The theoretical perspective related to conceptualization in a multi-method approach drew upon the sociological theory of phenomenology, realism within Marxist approaches and social actions which are described in the structurationist approach in explaining communities‟ capabilities and their resilience to extreme events. The aim was to understand the ways in which people in communities constructed their meanings and interpretation for their sustainable livelihoods in the context of vulnerability. A further theoretical justification for combining the two methods is that they provide what sociologists term duality of structure and agency (Giddens, 1976). I refer here to the macro-structural ways of understanding society which tend to call for a deterministic explanatory mode versus those micro-structural approaches which emphasize on creative and interactive explanation and processes. I believe that the macro structure in terms of water policies, environmental policies and regulatory or institutional or governance policies had a bearing on the issues being investigated and no one method could have adequately been used to provide explanation as to what needs to be in place in communities to offset adverse effects of climate change (drought effects). As Cain and Finch (1981) in agreement with Mikkelsen (1995) state that there is no one truth, life is multi-faceted and environmental problems are more complex hence discovering what really happens when people experience droughts needed to be investigated and analysed with more than one method, hence the used of mixed methods multi-method approach. This explanation provides a justification or the basis for using methodological pluralism in this study.

3.4.3 Strengths and weaknesses for using multi-method approach

As a matter of emphasis in this section 3.4.1 and 3.4.2, let me repeat in a summary on the advantages of the multi-method approach: It has the ability to confront contradictions and highlight the fragmented and multi-faceted nature of human consciousness. In addition, the approach increases both reliability and validity of data (Brannen, 1992) meaning that data collected from more than one source and using more than one method becomes more valid and reliable. In such way similarities and differences are exposed providing reasonable analysis in the process. Furthermore, Fielding & Fielding (1986) state that the careful and purposeful combination of different methods strengthens the breadth and depth of the analysis. The major problem of using such an approach is that one of them can just appear in data collection stage and disappear in the analysis section or the other way round with no explanation given as to why that has happened. In addition, there can be lack of clear explanation as to how the methods were used in the study and thirdly such an approach can be used with no theoretical explanation provided, as to why they are being used in the study and which aspects of the research problem they address (Denzin, 1970). To address such weaknesses of using multi-methods approach, the current study has i) shown in the research design table that both methods were used in data collection and analysis per objective (3.2); ii) provided explanation based on the reviewed literature as why and how the mixed methods were used in this study and iii) has been provided theoretical justification for the use of multi-method approach. Hence, the use of methodological pluralism is appropriate in this study.

3.4.4 Data type and their sources for the multi-method approach

The collection of primary and secondary data, as an empirical data, which were both of quantitative and qualitative in nature were conducted. Primary data were collected from households in Ha-Lambani Village. These households were believed to have in-depth knowledge and lived experience of water availability, demand and use. Secondary data were collected from various publications which included books, journals, reports, newspapers and internet sources. These sources provided a broader understanding of the issue under investigation beyond the study area. Primary data were to provide answers to the research questions. These data were used to show relationships between observed facts in this study and what exist in the secondary literature. Secondly, primary data were used to show how my empirical findings and analysis of the investigated issues agree or disagree with previously published work in the reviewed secondary data. In this section, this study has shown the link between theoretical framework and methodological pluralism (mixed methods approach) and why this study used such an approach.

3.5 Research methods for data collection and analysis

3.5.1 Quantitative data collection methods for objective 2 and3

The questionnaire was used to collect quantitative data on water demand and water use. Such a questionnaire had structured and semi-structured questions. It was flexible and questions were intended to capture quantitative data on water demand and use and factors determining such demand and water use for quantitative analysis. The semi-structured parts captured data for qualitative data for analysis on factors that explain water availability. The questions were divided into five main sections and were labelled section A: water availability; section B:water demand; section C: water use; section D: water governance and section E: Socio-demographic characteristics of the participants. The structure of the questionnaire that I used is shown in an appendix A. One of the advantages of a questionnaire is that questions and responses are prepared well in advance and this makes data collection easier and faster. Data analysis becomes fast because responses can be directly compared and easily aggregated. For example, during my data collection period many questions were asked within a short period of time. The questionnaire employed was flexible where questions could be asked in a different way for the respondents to be clarified, mainly in the qualitative sections. Places and order for the interviews were arranged. Interviews were done as planned.

However, the process of preparing a questionnaire is time consuming. Secondly, determining people's responses in advance prohibits them from expressing themselves freely on the issues they know because they have to fit their knowledge into the predefined categories of the variables. Even in the analysis the aim is to give a generalized picture of the issue being investigated without providing a detailed explanation of the picture presented in the results. Again the way respondents are selected may result into selecting someone who is not interested, enthusiastic and may eventually not be helpful in proving the required data. Administering a questionnaire presents problems especially where some people are hired who even after being trained may not present or rephrase certain questions correctly to capture the needed information. To solve this problem, the responses were constantly checked manually against each question to make sure that data collected reflected what the questions intended to ask. Despite such process being cumbersome, but it ensured the quality and reliability of the collected information from the respondents on the issues under investigation.

3.5.2 Quantitative data analysis methods for objective 2 and3

Indirect methods and regressions analysis within exploratory data analysis (EDA) method were used to analyse the quantitative data (Anscombe, 1973). EDA is a method for quantitative data analysis that employs a variety of techniques which are mostly graphical in nature in order to maximize insights into a data set, uncover the underlying structure and to extract important variables from the data set for analysis (Chambers *et al.*, 1983, du Toit & Stumpf, 1986). EDA guides a researcher on how to dissect a data set, what to look for, how to look for and how to interpret the output from the data set. The main role of EDA is to open-mindedly explore the data set to reveal its structural sects and gain some new but often unsuspected insights into data sets (McNeill, 1977; Tukey 1977 & Tufle, 1983). Various tables and graphs were used in this study for analysis. These were generated in a computer using SPSS software. For example, regression analysis was used to explore the relationships between dependent variables of water demand and water use versus independent variables as explained and presented in chapter 4. Multiple regression analysis method was preferred to show the associations/correlation between dependent and independent variables tested. Magnitude and type of relations among variables were compared, summarised and analysed in tables as presented in chapter 4 to show important factors for research questions.

3.5.3 Quality assurance on the quantitative data for objective 2 and3

All quantitative variables were coded and one questionnaire was used as a codebook. Quantitative variables were defined. The used of Eyes and Hands Forms Manager Software (EHFMS) for data entry process. In this software I scanned all questionnaires and then carried out verification process on the screen for each of them. After verification process, I transferred the data from notepad in the EHFMS to SPSS. Data quality was checked using maximum security level 9 which is the maximum security scale within the software and if the software is in doubt of the variable it is entering it asks for verification of that variable. The whole process was in four stages whereby the software scanned the questionnaire, then interpreted it, then run the control, and then verified each variable. Where there was an error such as missing data or non-response, it asked for verification then I corrected that error. This improved data quality and made the analysed results from SPSS output more reliable. Secondly, to ensure quality control on regression analysis model, tests of multicollinearity to check redundant variables, linearity to check outliers and normality to check normal distribution of population sample were carried out as explained and presented in chapter4.

3.5.4 Qualitative data collection methods for objective 1, 4 and 5

The researcher used semi-structured interview guides for the FGDs and individual in-depth interviews and field observation as data collection methods for the present study. Miller & Brewer (2003) stated that a semi-structured format of interviewing allows the participants to develop their answers in their own terms and at their own length and depth, but the researcher still has some control of the direction and focus of interview. The guide covered questions on description of water availability, water demand, water use, and local groundwater governance in terms of institutions, capability, resilient and sustainable livelihoods in terms of strategies. For the observations, the researcher observed some practices and listened to some conversations among residents while interacting with participants in the study area. This was one of the advantages of the researcher being fluent in the local language of the study area (Venda and Tsonga languages) because it meant that researcher had an insider perspective as well. The researcher also made short notes when observing the people's practices on water abstractions, water use and some elements of local groundwater governance around water sources. The researcher also took photographs of the water availability, water demand (abstraction) practices and water use practices and facilities to support field observations and descriptions as shown in chapter 4.

Data collection took place in 2014 alongside the main WRC project. The interviews were conducted after appointments were made and agreed upon with participants/residents. The Chief's place was used for all the interviews and FDGs with permission from the Chief. The duration for each interview was between 40 and 50 minutes. The researcher collected all the required data personally in Venda and Tsonga languages which are the two languages in Ha-Lambani Village which the language that the researcher and participants were most conversant with. All the interviews and FGDs were audio recorded which the researcher later transcribed verbatim. The researcher translated the transcripts from Venda and Tsonga languages to English which were used for the analysis.

3.5.5 Qualitative data analysis methods for objective 1, 4 and 5

Thematic analysis was employed for this study. Thematic analysis is one of the most common forms of analysis in qualitative research (Greg, 2012). It emphasizes pinpointing, examining, and recording patterns or themes within data (Baun & Clarke, 2006). Themes are patterns across data sets that are important to the description of a phenomenon and are associated to a specific research question (Daly, Kellehear & Gliksman, 1997). The themes become the categories for analysis (Fereday & Muir-Cochrane, 2006). Thematic analysis is performed through the process of coding in six phases to create established, meaningful patterns. These phases are: familiarization with data, generating initial codes, searching for themes among codes, reviewing themes, defining and naming themes, and producing the final report (Baun & Clarke, 2006). The analysis provided deep insights that enabled the researcher to understand the water demand and use situation in Ha-Lambani Village. Such insights enabled the researcher to provide explanations with regards to the desired implementation plan that would ensure effective local groundwater governance practices in the study area especially during drought events. The researcher first familiarized himself with the data by reading the transcripts and listening to the recordings several times. Sections of data were then initially coded. Subsequently, textual data were merged according to their codes. Then categories were developed by clustering similar codes together to form themes. After that, themes were reviewed to check if they formed a coherent pattern or not. Where themes did not fit the patterns, data pieces were reorganised and the validity of each theme was checked. At the end, data were integrated and interpreted using the tools and procedure as provided by the following authors (Dey, 1993; Gibbs, 2007; Robson,2011; Green & Thorogood, 2013).

However, the thematic analysis method has some limitations which include its potential to miss nuanced data research (Greg, 2012). Despite such limitations, the advantages of using the thematic analysis method in a qualitative research outweigh its limitations. For example, the use of thematic analysis is well suited to large amounts of data which is usually the case in qualitative studies enabling researchers to provide interpretation of themes which are supported by generated data. The use of the thematic analysis method is applicable to research questions that go beyond participants‟ experience so it expands the range of the study (Johnny, 2009; Greg, 2012). Based on these stated advantages, the researcher was able to use such a method for data analysis and interpretation of the findings thereby reducing researcher bias in order to address objectives 3 and 4 of the present study.

3.5.6 Quality assurance on or rigour in qualitative data for objective 1,4 and 5

I transcribed all the qualitative data from the notes that I collected from the field into a readable form. I took note of the comments on hesitations that participants were making in responding to some questions and the way participants were expressing themselves, for example, their direct quotations and nonverbal communications. As I was doing this open coding as described above, I took note of theoretical memos, that is, meanings of the new ideas emerging from the field notes (Flowerdew & Martin, 1997). I repeatedly went through all my fieldwork notes on qualitative data and started formalizing them into categories. I coded all ideas of the same meanings in groups and those with different meanings /ideas in other groups. Such classification gave me main codes and sub-codes as I continued going through my fieldwork data. Categorization helped me to organize data so that relationships are clarified and seen easily at glance (Flowerdew & Martin, 1997). This process facilitated my analysis. I used Microsoft word processing for editing, transcribing, coding and categorizing my qualitative data for the analysis of the collected data.

In addition to described processes followed in the above section, various aspects of rigour for this study were adhered to through trustworthiness or dependability aspects. This was done by asking similar questions to participants at different times to check the consistence of their responses (Brink, 1991; Creswell et al., 2000; Gibbs, 2007). The aim was to check if the different categories of participants provided similar responses on the same question. Triangulation was also used where different data collection methods were engaged as well as using different sources of information (Denzin & Lincoln, 1994; Patton, 2002; Creswell, 2013). Employing multiple data collection methods increases the credibility of the findings by eliminating or reducing errors linked to one particular method. The researcher used observations, FGDs and individual interviews to collect data from participants on the same subject. In this way, the researcher was able to cross-check or compare responses from different methods with different categories of study participants. Triangulation was used to adequately address the problem of rival explanations.

3.6 Statements on research integrity

For the present study, there were no data collected and analysed that required technical and legal consideration. However, in terms of ethical consideration, verbal permission was obtained from the Chief of Ha-Lambani Village. Participants were informed about the requirements for participation in the study including their autonomy (free to withdraw from the study at any time without any negative repercussions), risks (no harm) and benefits (results/feedback) of participation in the study. Participants were informed that participation was voluntary and they were also informed about being tape recorded. They were ensured of anonymity in that no names and personal identity would be disclosed to anyone other than the researcher. Collected data including tape recorders and field notes and researcher's reflective notes were kept in a safe place as suggested by Malterud (2001) and Shenton (2003). The study was conducted in the local languages (Venda and Tsonga) and all forms were written in English and translated to local language to ensure that all the participants fully understood what the study was all about before giving consent. Only participants who gave consent were allowed to participate.

3.7 Study limitation

The review of previous studies on water demand and use in rural areas of South Africa suggests that there were no description about how data on water demand and use is obtained in such areas, hence, no data on such parameters existed. In addition, no implementation plan existed for the local governance practice for groundwater at village/community level against which this study could be measured. In addition, since this study was conducted in only Ha-Lambani Village, the findings may not represent the same situation in the entire Thulamela local municipality where Ha-Lambani Village belongs, Vhembe district where Thulamela local municipality belongs and in the entire Limpopo province of South Africa where Vhembe district belongs. Ha-Lambani village and Lambani Village according to Kaotla (2013) and Botha (2014) refer to the same village or used to mean to the same village.

The present used both quantitative (objective 2 and 3) and qualitative (objective 1,4 and 5) methods. The philosophy behind qualitative methods is not to generate results that are representative of the sample but to develop themes and concepts that can be generalised under similar environments, but the quantitative methods aims for the opposite. However, the purpose of this study was not for generalisation of results but the research design was planned to collect and analyse data to provide useful insights on how data can be generated in unmetered rural areas on demand and use of groundwater especially during drought events. Such procedure on data generation could form the basis for analysing factors that influence water demand and use so that implementation plan can be developed to govern and manage groundwater during drought events. The qualitative aspect of the present study provides explanation on the procedure for data generation, demonstrating the implementation plan and application of the chosen theoretical framework whereas the quantitative aspects provide the reliability and validity of the computed results obtained in objectives 2 and 3 of the study.

Another limitation of the present study was design of the bigger WRC project which the present study was part of, in that the bigger project did not obtain the formal ethical approval letter and used questionnaire survey and focus group discussions (FGDs) only. To overcome such limitation, the researcher obtained verbal permission from the participants and used Key Informant Interviews in addition to the questionnaire survey and FGDs of the main study. The researcher explained to participants the importance of being honest in their responses during data collection period. The benefits of the study to participants and to the village and other stakeholders such as local municipality were also explained during the study.

CHAPTER 4: RURAL DOMESTIC WATER DEMAND AND USE

4.1 Introduction

Chapter 3 has described the research design and research methodology that were followed in addition to research methods that were used to collect and analyse data. The tools to ensure that the analysed results were objective, appropriate and adequate were applied resulting into reliable and valid results that were presented and discussed in the current chapter and the preceding chapters. This chapter has three objectives: i) to explain factors that influence water availability in the studied community using qualitative descriptive methods; ii) to demonstrate the procedure on how to generate data for assessing groundwater demand and use in unmetered rural areas; iii) to determine factors that influence groundwater demand and use using regression analysis. This thesis argues that, for the groundwater demand and use that sustain people's livelihoods at household level especially in rural areas during drought, factors that influence water availability must be understood; data on groundwater abstraction (demand) and consumption (use) must be available to assess the usage quantitatively; and factors that influence such demand and use must be determine to inform design appropriate interventions.

Healy (2010) reports that globally, statistics on groundwater demand and use at households" level especially in rural areas are not available and yet global statistics originate from country statistics which also come from statistics from various water sources. This observation informed the approach followed in this study on demonstrating the procedure on how to generate such statistics thereby providing a leeway for further refinement on such methods. Various scholars (Falkenmark & Widstrand, 1992; Gleick, 1996; Falkenmark & Vorosmarty, 2005) have reported that the current common methods in water demand and use rely on modeling approaches with limited measured data. Therefore, the use of the field measurement approach presented in this study though crude in nature is envisaged useful in generating observation data for validating models on water demand and use. Such generated knowledge needs to be shared with scientists, users, providers and managers of water resources to facilitate a successful intervention strategies that required during droughts.

4.2 Overview on assessing groundwater demand and use

Objective one of the present study was to investigate rural domestic water demand and use using indirect methods including factors that influence water availability in the studied area while the second objective was to determine factors for rural domestic water demand and use using regression analysis. To achieve part of the objective one on factors that influence water availability, physiographic characteristics of the study area have been presented and explained using various maps and photographs to contextualize groundwater demand and use. For example, literature has shown that globally, groundwater is a significant source of fresh water; however, comprehensive statistics are not available on groundwater abstraction (demand) and use (Healy, 2010). This scenario informed the basis to demonstrate generation of such statistics using unmetered rural areas in Lambani as a case study. Global estimates show that 1.5 billion people rely on groundwater for drinking (Clarke et al., 1996). The demand and use for groundwater has been increasing and shows no sign of abating for scientists to calculate the available amount of groundwater and how groundwater system gets replenished (Molden, 2007). One of such methods is to estimate the groundwater recharge i.e. the rate at which aquifer waters is replenished. Quantification of natural rates of groundwater recharge is vital for good governance and management of groundwater but its difficulty has led to the common use of estimates (Simmers, 1990). This study provides qualitative estimates on expected groundwater availability using field observations on various factors to ensure continued use of such waters during drought events.

One of the most vital factors for groundwater availability is recharge. This is one of the most important components of groundwater studies and the least understood aspect because recharge rates vary widely in space and time hence the most difficult aspect to measure (Fisher & Healy, 2008). Recharge is defined as the downward flow of water reaching the water table, adding to groundwater storage (Freeze & Cherry, 1979; Lerner et al., 1990). The norm is to present recharge either as i) a volumetric flow (Volume per unit time such as L3/T i.e. m3/d); ii) or as a flux (Volume per unit surface area per unit time such as L/T i.e. mm/yr. However, Healy (2010) recommends presenting recharge as a percentage of precipitation which this study would have used if data were available. Four types of recharge, namely, diffuse, focused, preferential and episodic exist as reported by (Xu & Beekman, 2003). Details on methods of recharge estimates are beyond the scope of this study but such details exist in (Xu & Beekman, 2003). However, the focus of this study is to explain the implications of recharge on groundwater availability for domestic water demand and use during drought events using different physiographic characteristics/physical factors.

Improved understanding on factors that influence the recharge and water availability is essential. For example, ASTM (2008) report that the rate, timing and location of recharge are crucial in groundwater supply studies like the present study on water demand and use because i) the likelihood for contamination moving into water table increases as the rate of recharge increases and ii) areas of high recharge are often associated with areas of aquifer vulnerability to contamination. Thus, location of subsurface facilities such as boreholes and waste disposal sites are often selected based on the knowledge of relative rates of recharge in the area. Therefore, identifying factors that influence water availability in the study area and establishing rural domestic water demand and use using indirect methods in the context of drought events were fundamental. In addition, the analysis on factors determining rural domestic water demand and use where regression analysis was used provided statistical robustness for the qualitative assessment on factors influencing water availability.

4.3 Groundwater availability using physiographic factors

This section uses physiographic characteristics to qualitatively explain factors that influence groundwater availability in the study area. The aim is to shed light on factors that need to be understood for water demand and use in the study. Such understanding will facilitate assessment on what people do to adapt and sustain their livelihoods during drought events with regards to water demand and use. Such assessment will provide a basis for designing a community-based practical plan for good governance and management for water demand and use during drought events in small rural areas such as Ha-Lambani Village.

4.3.1 Physiographic factors that influence groundwater availability

The following physiographic factors were identified to explain how each one of them influence groundwater availability in Ha-Lambani Village: a) Climate in terms of precipitation, b) soil and geology, c) topography, d) hydrology, e) land cover and land use including settlement pattern. These physical factors were explained from the recharge mechanism perspective. From hydrology perspective, recharge mechanism as indicator of groundwater availability, thus, qualitative assessment of such factors remains vital because the explanation provides a basis for measuring or quantifying the contribution of each factor towards water availability in particular area or catchment (Xu & Beekman, 2003). Therefore, before quantitative analysis of demand and use of groundwater and the factors that influence such demand and use, it was thought that factors that influence availability of such resource be assessed qualitatively to provide insight on what to measure first.

a) **Climate (precipitation)** is one of the potential factors that influence groundwater availability. Healy (2010) outlines four climatic regions in relation to recharge, namely, i) Arid climates with annual precipitation of less than 250 mm which are likely to experience episodic and preferential recharge, ii) semi-arid climates with precipitation rates of between 250 and 500 mm/yr which are likely to have episodic and preferential recharge, iii) sub-humid climates with annual precipitation rates that range from 500 to 1000 mm/yr are likely to experience focused and diffuse recharge, iv) humid climates with annual precipitation rates that exceed 1000 mm/yr. Being in semi-arid climate, Ha-Lambani Village in South Africa is expected to experience episodic and preferential recharge although diffuse recharge and focused recharge are also considered the norm (Fig. 13). Largely, South Africa experiences semi-arid climates although some areas experience other climates (FAO, 2008). Among the climatic variables, precipitation is the major sources of natural recharge hence the focus on rainfall data for this study area (Fig. 14). For instance, Lorenz & Delin (2009) reported the effects of precipitation on recharge mechanisms when temporal variability (yearly and seasonal) frequency, duration and intensity of precipitation events are considered. The two authors summarised that the area experience more recharge when precipitation rates exceed evapotranspiration rate to enable drainage to occur. However, Healy (2010) reported that in semi-arid region the opposite is true because evapotranspiration rates exceed precipitation rates leading to a less recharge which leads to less water availability especially groundwater. This scenario suggests that Ha-Lambani is likely to have less groundwater available and with the drought, such a situation can be worse, hence, appropriate plan need to be implemented to ensure good governance practice for sustainable use and management of such resource to sustain people's livelihoods especially during drought events.

Figure 10:Ha-Lambani Village within Semi-Arid Area

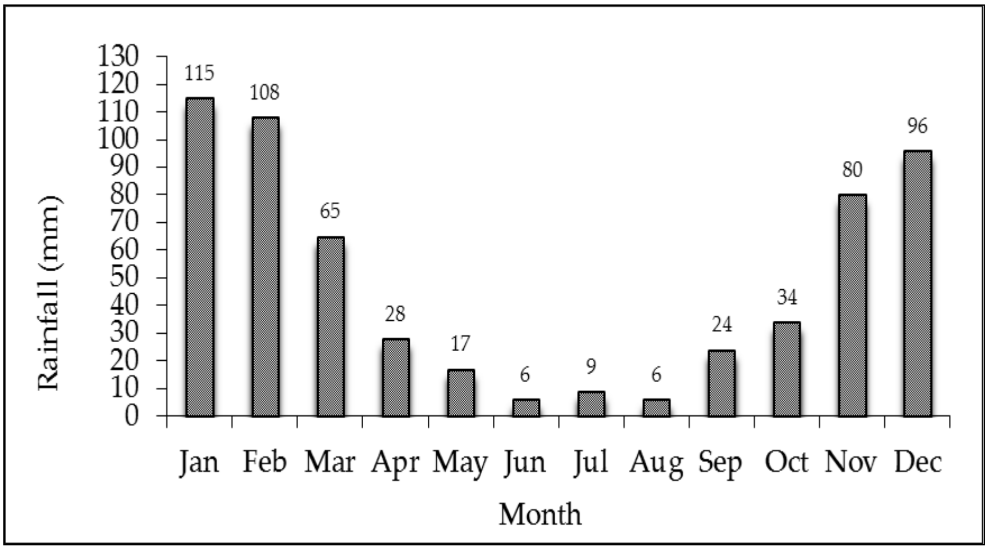


Figure 11:Average monthly rainfall (mm) for Ha-Lambani Village

Fig. 11 shows that Ha-Lambani area receives summer rainfall with highest rains in months of September to March with wither months of May to August receiving low rains. The average monthly rainfall varies slightly for each month, but the seasonal trend is constant suggesting the yearly monthly rainfall pattern is within the expected semi-arid environment. Ha-Lambani area receives more rainfall in summer (rainy season) than winter (cool-dry season). The rainy season (October to April) is yearly wet and the cool-dry season (May-September) has lower monthly rainfall. This low rainfall situation is made worse by occurrence of drought events which increases high evaporation rates (Healy, 2010). To assess the long-term trend of rainfall which is essential for groundwater recharge interpretation among other factors, it is more accurate to use rainfall figures as far back as possible which this study did not collect. This weakness makes the presented information proxy of rainfall pattern in Ha-Lambani and implication for groundwater recharge in that sense remains qualitative. However, such results indicate good qualitative indicator of groundwater availability holding other factors constant.

Although this study is not about methods to estimate recharge rates, basic understanding on the relationship between rainfall and recharge is essential. For example, Beekman et al. (2007) showed improved estimation of recharge and flows in aquifers for assessing the relationship between rainfall and recharge. However, from the qualitative perspective, the importance of the results from Ha-Lambani on rainfall pattern indicates the months that had more rainfall and more replenishment to aquifers in the area. This observation agrees with Beekman & Xu (2003) who concluded that understanding climatic changes such as rainfall pattern especially in some parts of Southern African countries improves knowledge among water scientists and managers in terms of whether or not replenishments of aquifers are more or lesser during particular rainy seasons or drought events. Therefore, it can be inferred that the assessment showed that the drought events reduces groundwater recharge and thereby making groundwater availability worse during such periods. While this interpretation is not conclusive, such results provide useful insights on practices/plan that need to be designed to govern and manage water resources in drought prone areas such as Ha-LambaniVillage.

b) **Soils and geology:** The relationship between soils and recharge is that recharge is more likely to occur in areas that have coarse-grained and high permeability soils as opposed to areas of fine grained and low permeability soils. For example, Robinson et al. (2008) showed that coarse grained soils have a relatively high permeability and are capable of transmitting water rapidly. The presence of these soils promotes recharge because water can quickly infiltrate and drain through the root zone before being extracted by plant roots. In Ha-Lambani Village, the majority of soils in the upper terrain unit are shallow with coarse characteristics and the valley terrain unit has are moderately deep soils with depositional, alluvial and clay characteristics (Joseph & Botha, 2012) suggesting presence of alluvial aquifer along the valley with relatively high yield while upland suggest low yielding aquifer.

Apart from soil characteristics, geology of the subsurface controls the recharge mechanisms. For example, if the rate of discharge from aquifer is less than the rate of recharge due to the nature of subsurface geology, water storage within the aquifer increases. Robinson et al. (2008) found that aquifer storage when it reaches a maximum point; additional recharge is not accepted regardless of the amount of precipitation. The authors concluded that apart from precipitation and soil features, subsurface geology needs to be understood in terms of the recharge mechanism. The dominant geology for the area is hard rock formation of the granite, gneiss, Schists and Sandstone forming basement complex aquifer which has limited aquifer storage capacity suggesting that the additional recharge from more rainfall is not accepted (Robinson et al., 2008). This possibly explains the presence of flash-floods during rainy seasons that were reported during field visit in the study area.

The dominant soils sandy-clays with top geology being sands and gravels with coarse grains will lead to high permeability and capability to transmit water rapidly to aquifer but the deeper basement complex geology in this area will not change the limited aquifer storage capacity. Yet, such knowledge is essential for design a local governance and management practice for water use especially in rural unmetered water area such as Ha-Lambani Village.

Figure 12: Dominant soils and geologic features that influence groundwater availability (Photo : Lebese, 2014)

c) **On topography,** Stonestrom & Harrill (2007) empirically concluded that land-surface topography plays an important role in groundwater recharge mechanism. Of importance, the authors showed that steep slopes tend to have low infiltration rates and high runoff rates leading to low recharge rates. They concluded that local relief, orientation/slope aspect and altitude of mountain ranges are additional topographical factors that influence the recharge mechanism. In line with the results of these two authors, this study used satellite images (Fig. 12) to show the nature of topographic feature in the area. The study used observation methods to produce photos that revealed different topographic features that could be associated with recharge mechanism in Ha-Lambani Village (Fig. 12).

Figure 13:Local relief, land-cover and land-use influencing groundwater recharge (Photo:lebese;2018)

Field observation methods showed that the present of local relief and the general location of Ha-Lambani Village being between highlands (Fig.13) suggest that the entire Ha-Lambani area is a discharge area. Though these findings are not conclusive, they provide i) useful insights on factors that control groundwater availability and ii) the basis to urge the prompt implementation of local governance and management practice. Such qualitative knowledge need to be shared during stakeholder meetings as a starting point for designing a collaborative and sustained community-based initiative for local governance and management practices for water availability, water demand and water use especially during drought events.

d) **The hydrology** of Ha-Lambani area has been presented in (Fig.13) and supplemented by the photographs in (Fig 15) showing that surface water resource are limited apart from having one perennial river called Livuvhu River. This situation suggests that Ha-Lambani is more groundwater dependent for domestic water supply. In addition, the quality of water in the Livuvhu River is not fit for domestic use(Personalcommunication,2014).It was reported and observed that streams in Ha-Lambani were few and were non-perennial in nature recharging groundwater system (Fig. 13) apart from the Livuhvu River (Fig. 14).

Figure 14:The section shows Livuhvu River as Perennial River for water availability (Photo: Lebese, 2014)

e) **On Land cover and land-use**, recent studies (Leblanc et al., 2008 & Brunner et al., 2007) have shown that vegetation and land-use as factors have great influence on the recharge mechanism. The authors state that types and densities of vegetation control patterns of evapotranspiration and abstraction rates. They confirmed that a vegetated land surface showed a higher rate of evapotranspiration than a non-vegetated land surface under similar conditions thereby explaining the less water available for recharging groundwater. They continued to argue that tree roots abstract water from deeper depth than shallow-rooted crops and that tree canopies intercept more rainfall. Their studies suggest that more dense forested areas reduce recharge rate while increasing discharge rate through tree-root abstraction and tree-canopy interception. Mucina & Rutherford, (2006) reported that the Ha-Lambani has rangeland vegetation which was classified veld type of vegetation which is described as the Soutpansberg Mountain Bushveld. This veld type typically consists of a dense tree layer with a canopy cover of 60-70%, and a poorly developed grassy layer. At the top of the mountain there is a plateau with relatively open savanna sandveld on both deep and shallow quarzitic sands. There is also dwarf shrub which forms dense stands, especially on overgrazed mountain summits and rocky outcrops (Van Wyk & Malan, 1988 & Pooley, 1998).

Field observations confirmed the reports by Van Wyk & Malan, (1988) & Pooley, (1998) Mucina & Rutherford, (2006) that Ha-Lambani area has rangeland vegetation and relatively open savanna sandveld. In addition, the study area has practice subsistence farming which is dominated by vegetable as the main agricultural activity. Being in semi-arid, the types of vegetation cover in this study area (Fig. 16) suggest the expected low recharge rate, hence less groundwater availability. However, the understanding of the influence of such features on water availability among water scientists, water developers, water users and water managers at village level has positive potential influence on bringing them together for a successful implementation plan for good governance and management of the water resource.

Figure 15:Relationships between land-cover/use with groundwater availability (Photo:Lebese,2014)

Figure 16:Influence of vegetation and/land covers on groundwater availability (Photo:Lebese,2014)

The assessment by Leblanc et al., (2008) has shown that this type of vegetation contributes to reduction on the groundwater recharge mechanism. It can be said that the study area is expected to have reduced recharge to groundwater hence less groundwater availability. Although the assessment by Leblanc et al., (2008) meets theoretical principles of scientific explanation, the reality is not that straightforward. For instance, the influence of vegetation is seasonal, decay roots/shrinking roots provide preferential recharge flow paths that speed up recharge rate and farming practices where ridges are made provide focused recharge areas that enhances recharge rates (Brunner et al., 2007). Field observations showed Ha-Lambani area had farming ridges in the gardens which formed focused recharge areas (Fig. 15). Such revelation forms the starting point of discussion with all villagers and stakeholders on how groundwater can be made available with such practice. The farming ridges accelerate more water into the aquifer but such water might be contaminated with chemical applied in crops in such ridges. In addition, (Fig. 13) showed that the study area exist at a lowland area/slope area thereby making Ha-Lambani Village a discharge zone (Fig.13). The discussion with stakeholders who have varied knowledge, skills and experience about water aspects will need to be validated the field observation results hence the use qualitative approach. The use of field observation was thought to facilitate consensus about the scientific knowledge that needs to be understood among all stakeholders for designing appropriate implementation plan for groundwater governance and management especially during drought events where the water demand and use become critical to sustain people livelihoods.

4.4 Procedure to generate data on domestic groundwater demand and use

Section 4.3 has addressed objective in on qualitative assessment of factors that explain or influence groundwater availability in an area. This section 4.4 present results on objective 2 which assessed rural domestic water demand and use using indirect methods. The focus was to demonstrate the procedure on how to generate statistical data for assessing groundwater demand and use for domestic purposes at household levels in unmetered rural areas for implementing good governance and management of water resources. The argument is that the designing of implementation plan to enforce good governance and management of groundwater should be based on quantitative understanding of the demand and use of such water at household level in an area; and where statistical data is scarce or absent, a crude procedure should be designed and tried to show how such statistical data can be generated. This section 4.4 provides parameters that were used to compute such statistics (4.4.1), data collection procedure on such parameters (4.4.2) and computational procedure that was followed to generate statistics on demand and use of groundwater (4.4.3). The reason for a detailed description on the procedure that was followed to calculate such statistics was to provide leeway for further refinement so that measures to govern and manage water are based on measurable/quantitative analysis that continue to be modified newer innovative ways.

4.4.1 Selecting parameters for a computational approach

This section 4.4.1 provides parameters that were identified and used to compute statistics on demand and use of groundwater in Ha-Lambani Village. The following were the identified parameters that were specified: i) households; ii) household size; iii) type of water source; iv) proportion of users; v) measured distance of users from water sources using South Africa recommended distance of household from water sources as a benchmark; vi) sanitation types; vii) amount of water requirement per person per day in litres; viii) amount of water use per person per day in litres. Reasons for choosing these factors are provided below:

The number of households that were available and habitable in Ha-Lambani Village during the time of fieldwork and number of people per household were documented through hydrocensus. The understanding is that water demand and use depend on the number of occupants in each household which determine the amount of water required and used per day due to their associated activities. In Ha-Lambani Village, the number of households was obtained from the National Census (Stats SA, 2014). For validation, a local census survey was conducted during the hydrocensus period and the latter was adopted for use in this study.

The types of water sources, number of households using a particular water source and types of sanitation facilities were identified and enumerated during hydrocensus using a questionnaire. Since this study focused on groundwater sources, only boreholes (BHs) and open wells (OWs) were identified and enumerated. Pit latrines and pour-flush latrines were identified and enumerated to analyse the water use in such latrines. Only households using groundwater sources were identified and enumerated to assess the amount of groundwater abstracted from the aquifer per day. The focus on groundwater sources was based on the thinking that such sources provide safe drinking water which are crucial sources of water during drought as discussed in the literature presented in chapter 2 of this thesis.

The distance from households to groundwater sources for drinking such as BHs and OWs were measured. This was roundtrip distance in metres using measuring tapes. Those households falling with 1000 metres were considered near to their water source and those beyond 1000 metres were considered far from their water sources (WHO, 2009). Measuring the distance and proportion of households near and far from water sources for drinking was used to assess the status on access to safe water source during drought. WHO (2009) defines basic access to a safe water source as the number of people with minimum quantity of 20 litres of water per capita per day within a maximum distance of 1000 metres from the source. Access is measured by assuming that a borehole serves a population of 250 people while a communal standpipe serves a population of 120 (Foster et al., 2000 & MacDonald, 2005).

Healy (2010) reports that comprehensive statistics on groundwater abstraction (demand) and use are not available, although it is estimated that more than 1.5 billion people worldwide depend on groundwater for potable water supplies. However, about 1.1 billion people fail to have access to safe drinking water sources and many of these live in rural areas (Foster et al., 2000 & MacDonald, 2005). In Sub-Saharan Africa, 300 million people lack access to safe water supplies of which about 80% live in rural areas. However, in South Africa, the 2011National Census of South Africa reports that 91.2% of households had access to piped water, either inside their own homes or yards or from communal taps while 8.8% (about 4.5-million people) had absolutely no access to piped water (StatsSA, 2014). This positive picture can change with drought if such water comes from surface water. Hence, the focus of this study on groundwater sources which is resilient to effect of droughts. This principle informed this study to assess the amount of water abstracted from groundwater (water demand) and the amount of water actually used (water use) at household level per person per day, per household per day and in Ha-Lambani area per day. Although such calculations are not comprehensive, they provide useful insights on the amount of groundwater abstracted from aquifer and used in unmetered rural areas experiencing drought effects.

4.4.2 Procedure and results on generating data for domestic water demand and use

This section 4.4.2 presents the process that was followed to generate data on each of the identified parameters and findings thereof. During hydrocensus a questionnaire was used to record the total population, total number of households and average households‟ size, number of water types and number of pit-latrines in each of the eight studied compounds. The findings are presented in two parts i) per compound in Ha-Lambani area and ii) the total for the area of Ha-Lambani (Table 2). Despite the focus on groundwater sources, it was noted that there were three communal stand pipes present in the study area during the fieldwork, one perennial river called Luvuvhu River. No household reported the use of pour-flush toilets hence only pit-latrines in Table 2 are presented as the available sanitation facilities.

Table 2:Selected parameters for calculating domestic water demand and use

Selected variables	**Results from selected compounds (C) in Ha-Lambani Village**								
	C1	C2	C3	C4	C5	C6	C7	C8	Total
Total households	42	173	99	54	109	74	38	100	689
Ave household size	6.0	5.4	5.3	5.9	6.0	5.5	4.9	5.2	5.525
Water source (BHs)	0	2	2	2	3	3	2	3	17
Water source (open)	1	0	2	1	1	0	1	0	6
Pit-latrines	33	110	76	53	88	54	26	76	516
Population	253	940	527	316	650	408	188	523	3805

Note: C = Compounds or sub-communities within the clusters in Ha-Lambani Village

Table 2 showed the reported statistics generated on the variables from the studied compounds or sub-communities. Such generated data on HH size in the studied compounds did not align with the data from the national census which showed that the average household (HH) size of 3.7 in Ha-Lambani whereas Thulamela local Municipality, Vhembe District Municipality and Limpopo Province had average HH size of 3.9, 3.8 and 3.7 respectively (Stats South Africa, 2014). All these HH sizes are much higher when compared to the South Africa national HH size of 2.2 (Stats South Africa, 2014). The variation on statistics for HH size in the study area could be due to over-reporting error as respondents could have had varied perceptions about the survey which is common. Nevertheless, such information on HH size was thought vital when assessing water demand and use with regard to amount of water withdrawn from water sources and amount of water consumed at household level.

To generate statistics on domestic water demand and use at household level in Ha-Lambani area, the following procedure was followed: Water demand in this study referred to the amount of water abstracted from groundwater sources and carried to respective households per day (Wallingford, 2003; Molden, 2007; Healy, 2010). Water withdrawers carry their water largely in plastic pails (Fig. 17). To compute water demand, the water in water collectors‟ containers was poured in 20-litre calibrated plastic bucket and readings were recorded. This was done for all sampled households. To measure the actual water use, the unused water from the previous collection was measured in the 20-litre calibrated plastic bucket. The recorded amount of unused water was subtracted from the water collected water (demand). The difference was the water that was actually used. We computed for these three categories, namely, water abstracted (water demand), water actually used (water use) and the unused water (left over water or excess water) and entered the statistics into SPSS software for computation. The computations were at three levels: a) water demand per person per day, water demand per household per day and water demand in a village per day; b) water use per person per day, water use per household per day and water use in a village per day; c) water unused per person per day, water unused per household per day and water unused in a village per day as per presented in Table 3.

Figure 17: Plastic buckets/pail that water withdrawers carry their water from BHs(Photo:Lebese;2014)

To simplify the process, the average water demand, water use and water unused per day per household was crucial to be computed. After computing that figure and when the figure was divided by the average household size, it gave us the water demand or water use or water unused per person per day and when that number was multiplied by the total number of households in the study area, it gave us the water demand, water use and water unused in the study area per day (Table 3). Such results were compared with the methodology that Wallingford (2003) proposed to calculate water demand and water use for sub-catchments as applied in River Kadzi sub-catchment in northern Zimbabwe. For comparative analysis the Wallingford approach has been applied in the present study and results in Table 4.4 show no major difference but his method is cumbersome. However, the implication of the procedure and the generated statistics are discussed in terms of their importance to improve calibrating models that estimate water demand and use especially groundwater resources at village level or sub catchment or catchment scale during drought events.

Table 3:Average rural domestic water demand and use in litres per day

Domestic Water categories	Person per day (litres)	Household per day (litres)	Sub-catchment per day (litres)
Water demand	21.2	116.91	80,550.99
Water use	16.8	92.55	63,766.95
Water unused	4.4	24.36	16,784.04

4.4.3 Computing rural domestic water demand and use

Direct and indirect methods are the two main methods used to assess water demand and use for domestic purposes in rural areas at catchment level. Direct methods use socio-economic surveys and participatory techniques by involving relevant stakeholders to estimate the current and future water demand and use. The focus is to predict the future trend based on the present pattern. The basis for promoting direct method approaches is supply-driven projects, where water is simply delivered to communities with little or no involvement of community members (Alcock, 1986). Direct methods are primarily designed for detailed planning of rural water supply schemes such as feasibility and design studies which are typical of the engineering approach to water development (Webster, 1999). This study used the mixed-method approach whereby involving community members to manage their water was considered essential for sustainability. Thus, the indirect method was considered appropriate.

In the present study, the indirect methods were used to compute the quantity of water consumed from population levels and then estimate demand levels in terms of per capita consumption. Alcock (1986) observed that in general, estimating rural water demand and use is difficult because of: i) many of the rural water supply systems are unmetered, ii) data concerning domestic water demand and use are often expensive to generate and time consuming to collect and iii) the level of service provided by the water supply system is often unknown. This observation was the basis of the current study which focuses on demonstrating a methodology of generating data on demand and use of water in unmetered rural areas during drought events. For good governance and management of water resources at village level, indirect methods are the most appropriate for establishing the total rural domestic water demand and use (Turton et al., 2001). This approach considers the total households in the study area, the average household size (5.5), the proportion of the householdsthatarelocatedbelowandabovethenationalsetmaximumdistancefromwater sources and the amount of water required and used per person per day in the study area. The computation from such an approach provides the total rural domestic water demand and use for either the entire village or the sub-village. Such information when shared among scientists, developers, users and managers of water resources has the potential to govern and manage water effectively especially in unmetered rural areas during drought events.

Since the current study focused at assessing factors that influence water demand and use in unmetered rural areas during drought events in order to design implementation plan for a local groundwater governance practice, indirect methods were used to generate statistics on rural domestic groundwater demand and use using Ha-Lambani Village as a case study. The aim was to demonstrate the feasibility of such methods as an entry point for lobbying the practical local groundwater governance framework as an intervention during drought events. Kgathi (1998) cautions that the accuracy of a demand assessment is a tradeoff between the budget needed for an accurate demand assessment and the predicted usefulness of the results obtained from such an assessment. Based on Kgathi's thoughts, the computational procedure with associated statistics presented on Ha-Lambani Village provided useful insights and platform towards implementing a working plan for local groundwater governance where managers, users, developers and researchers of water would use such results as a starting point in their collaborative efforts in managing water resources especially during droughts.

Wallingford (2003) suggested applying an indirect method to calculate rural domestic water demand and use for the effective management of water resources at the catchment level. To apply the suggested formulae presented below, the number of water users above and below the maximum set standard by South Africa was added to the factors used to compute domestic water demand and use in Table 4. That proportion of users per specified water source versus distance from their households was established through the hydrocensus where respondents were interviewed on the number of people accessing water sources and the associated reasons for such access. This was followed by field observation to validate the reported responses. Distances from sampled households to water sources were measured using measuring tapes although a better measuring device could have been used.

Baumann & Danert (2008) suggested that one groundwater source to serve 250 people and the required maximum distance from the water source to a household is 500 metres although WHO (2009) recommends 1km. The principle in access to safe water is that the distance from the household to water sources influences the amount of water demanded and used at household level which has implications on improving human health and their productive livelihoods especially during drought. Wallingford, (2003) in differentiating water use and water demand, stated that although the two have different conceptual meanings, in reality, water demand refers to water consumption or water that is abstracted or withdrawn from its source while water use refers to the actual use of water after being abstracted from the source. He gave an example that within rural parts of southern Africa, theoretical water demand considerably exceeds the actual water consumption. As operational definitions in the present study, water demand refers to water withdrawals or water abstracted from groundwater sources and water use refers to actual water consumption at household levels.

Applying Wallingford (2003) indirect method to this study, findings indicated that 63% of households were located within 500 m from water sources and such households were using pit latrine for sanitation. The averages of water demand and use per person per day in those households were 21.2 and 16.8 litres respectively (Table 4). The averages of water demand and use per household per day were 116.91 and 92.55 litres respectively (Table 4). The South African Government recommends 25 litres per person per day while the international standard recommends 50 litres per person per day (Brown et al., 2011; Baumann & Danert, 2008; Gleick, 1996).The current study assessed the compliance to both guidelines as a starting point for good local governance and management practices for groundwater in rural areas from the context of vulnerability i.e. during drought events.

Table 4:Water demand, use and unused in litres with distance from sources

	HHs <500m from water source (63%)			HHs >500m from water source (37%)		
	Demand	Use	Unused	Demand	Use	Unused
Per Person	21.2	16.4	4.7	21.1	17.3	3.8
Per HH	117.0	90.8	26.2	116.8	95.6	21.2
At Village	6,786.0	5,266.4	1,519.6	3,971.2	3,250.4	7,20.8

The computational approach that was adopted for calculating the total rural domestic water demand and use for Ha-Lambani Village using the indirect method as suggested by Wallingford (2003) gave the following results:

a) Water demand = Water demand for households that are located more than 500 m away from a groundwater source x number of households x average households size x water demand per capita = 0.37 x 689 x 5.5 x 21.1= **29,584.6265 litres per day** plus water demand for households that are located less more than 500m away from a groundwater source x number of households x average households size x water demand per capita = 0.63 x 689 x 5.5 x 21.2 = **50,612.562 litres per day.** Therefore, the total rural domestic water demand for Ha-Lambani Village is estimated at **80,197.1885 litres per day.**

b) Water use = Water use for households that are located more than 500 m away from a groundwater source x number of households x average household size x water use per capita = 0.37 x 689 x 5.5 x 17.3 = **24,256.5895 litres per day** plus water use for households that are located less than 500 m away from a groundwater source x number of households x average household size x water use per capita = 0.63 x 689 x 5.5 x 16.4 = **39,153.114 litres per day**. Thus, the total rural domestic water use for Ha-Lambani Village is estimated at **63,409.7035 litres per day.**

c) Unused withdrawn water = Unused withdrawn water for households located more than 500 m from a water source = 0.37 x 689 x 5.5 x 3.8 = **5,328.037 litres per day** plus unusedwithdrawnwaterforhouseholdslocatedlessthan500mfromawatersource= 0.63 x 689 x 5.5 x 4.7= **11,220.7095 litres per day.** Thus, the total rural domestic unused withdrawn water for Ha-Lambani Village is estimated at **16, 548.7465 litres per day.**

From the above process on how computational procedure in the indirect method are conducted, this study provided a simplified version of such an indirect method by focusing on fewer parameters, namely, water demand, water use, total households and household size. The computation with such fewer parameters yielded similar results (Table 5). In this way, our proposed approach was cost effective and pragmatic to implement. The process is also modern based on scientific principles of systematic field measurements accompanied with statistical analyses using the IBM SPSS software version 19 with robust quality control tests before analyses. With such fewer computational steps, the proposed approach is deemed acceptable socially and politically among water stakeholders, namely, water researchers, water users, water providers and water managers. In that way, our approach provided one step towards facilitating a practical local governance framework as it forms a platform to discuss and implement collaborative efforts among stakeholders in rural areas

Table 5:Water demand, use and unused in litres with distance from sources

Results when Wallingford (2003) approach was applied on our data set (liters)						
	HHs <500m from water source (63%)			HHs >500m from water source (37%)		
Categories	Demand	Use	Unused	Demand	Use	Unused
Per Person	21.2	16.4	4.7	21.1	17.3	3.8
Per HH	117.0	90.8	26.2	116.8	95.6	21.2
Village	50,612.6	39,153.1	11,220.7	29,584.6	24,256.6	5,328.0

Results when the proposed approach in this study was applied on our data set (liters)			
Categories	Water demand	Water use	Unused water
Per person	21.2	16.8	4.4
Per HH	116.91	92.55	24.36
Village	80,550.99	63,766.95	16,784.04

HH= Household; Village. All calculations in the table are per day (daily basis)

Agreeing with our proposed approach, Wallingford (2003) reported that methodologies to assist planners and managers to assess water availability in rural areas or catchments exist, although procedures to generate data for such methods are scarce. However, little is available to assist in assessing water demand and use especially domestic water demand and use in rural unmetered environments. Therefore, the current study aimed at contributing to narrow such a gap by demonstrating the application of the available indirect method with observation field data and modified its computational procedure. The modified approach has shown how data on rural domestic water demand and use can be computed with fewer parameters but producing similar results to indirect methods as shown in Wallingford (2003) in Table5

Table 6:Monthly and yearly water demand, use and unused in Ha-Lambani Village

Water consumption per time in litres (day, month, year in litres)	Categories of water consumers (water in litres)		
	Per person	Per household	Per Village
Water demand per day	21.20	116.91	80,550.99
Water demand per month	636.00	3,507.30	2,416,529.70
Water demand per year	7,632.00	42,087.60	28,998,356.40
Water use per day	16.80	92.55	63,766.95
Water use per month	504.00	2,776.50	1,913,008.50
Water use per year	6,048.00	33,318.00	22,956,102.00
Water unused per day	4.40	24.36	16,784.04
Water unused per month	132.00	730.80	503,521.20
Water unused per year	1,584.00	8,769.60	6,042,254.40

Table 6 shows that although statistics for water demand, use and unused per person, per household and per village per day are relatively small, such statistics are huge when analyses are conducted on monthly and yearly basis. Ha-Lambani Village being a case study in rural area, such statistics provides significant key insights on how much groundwater is abstracted and used in a particular area. Such revelation is important in the context of increasing population with their associated demand for water to meet their livelihoods activities and also with the increasing effects of climate variability (drought) on water resources especially on groundwater resources. These insights justify the need for designing a practical implantation plan for enforcing good governance for groundwater resources in the context of drought.

To strengthen the above argument, regression model in SPSS software using water demand, use and unused as dependent variables could have been used to correlate with population, and climate change factors (average temperature and rainfall) as independent variables. This could have assessed the direction and magnitude of climate variability effects on water demand and use. The results would have helped to suggest effective adaptation measures at local level so that people's livelihoods are not seriously affected by effects of drought. Unfortunately, there were no adequate temperature and rainfall data for Ha-Lambani Village that would have enabled such calculations. Nevertheless, this study has revealed the need to have such database to enable assessing detailed daily, monthly and yearly water consumptions pattern at village level. Mohamed & Al-Mualla (2010) used SPSS software to calculate water demand and actual water consumption in United Arab Emirate and found that such calculations provide bases for forecasting scenarios on water demand and use in the water supply sector. The procedure and findings in the present study provide a basis for further studies on water demand and use at village level for various types of analyses.

4.5 Determinants for rural domestic water demand and use

Section 4.5 addresses objective 3 on factors that determine or influence rural domestic water demand and use. To estimate factors that determine rural domestic water demand and use at household level, a regression model which is a traditional model for water demand was used. We used a regression analysis to model the relationship between a response/dependent variable (water demand and use) and several explanatory/ independent/ predictor variables. In statistical modeling, regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and independent variables. We also used correlation analysis to compare the strength and direction of relationships among predictors. We used SPSS (Statistical Package for Social Scientists) statistical software to determine the presence or absence of the relationship between variables including their strength and direction.

4.5.1 Description of how data was collected for regression analysis

Hydrocensus was conducted where the household questionnaire which consisted of five parts was used to assess the factors that influence groundwater demand and use at household level in Ha-Lambani Village. The first part dealt with water demand and use in terms of asking the amount of water withdrawn/abstracted/collected (water demand) from sources for each sampled household and the amount of water used at each sampled household. Both the reported water demand and use were then measured in litres using the calibrated 20/litre plastic pails. Questions on factors that influence such demand and use were also asked from the same sampled households. Part two of the questionnaire consisted of questions on the respondents" perceptions of the water quality from sources they collected the water. The water quality aspect was not analysed for this thesis. The third part of the questionnaire dealt with institutional management of groundwater in terms of collaboration among water developers, water users and water funders/managers. Responses from this section are presented and discussed in chapter 5 of this thesis. The last part addressed with demographic, educational and settlement pattern aspects of respondents in the sampled households. Responses from such questions were incorporated in chapter 3.The regression analysis was used to estimate significant factors that influence water demand and use.

4.5.2 Determining factors for computational procedure of regression analysis

Our dependent variable for water demand is the amount of water (litres) carried home per day by household members divided by the total number of individuals in the household (water demand per capita per day). For water use, the only difference is the amount of water actually used per individual per household per day and the rest remain the same. We have used the Multiple Regression Analysis Model (MRAM) as a traditional water demand model in which our dependent variable (water demand and use) is hypothesized to be a function of several independent variables as presented in Table 7 with their expected signs and directions.

Table 7:Explanations on expected signs and direction on independent variables

Variables	Explanation on expected sign and direction in the regression model
HH SIZE	Households with more people were expected to demand & use more water.
EDU	Households with formal education were expected to demand & use more water.
PWOMEN	Households with more women than men were expected to draw (demand) & use more water since water collection is the duty of women in this area. Results showed that (98.9%) were women collecting water from sources.
SRELIABILITY	The source that produced water all year round was expected to attract more users. Availability of water at source all year round was expected to result in high demand hence frequent use meaning more water withdrawn.
GWQUALITY	HHs that perceived good quality of water from sources were expected to have high demand and high use of such waters.
DISTANCE	Households located more than 500 metres round trip from groundwater sources, are expected to demand less water and use less water because long distance leads to low demand and low water usage at household level.
WPCOMMITTEE	Presence of water point committee indicated active community involvement in governing and managing water demand and use
REGULATIONS	Number of respondents who showed awareness of water rules implied possibility of complying to such rules when water point committee members enforce them
EFFECTIVE USE	Respondents who reported that safe water sources are used effectively were expected to draw and use more water from such sources

From table 7, first, households with more people **(household size**) were hypothesized to use more water per capita because activities of many people require more water. The question was: How many people live in this household that uses this water?). Secondly, we assumed that households with **formal educated members** will demand and use more water because formally educated people are expected to be more aware of health benefits of water use. The question was: What is the educational level of members of this household? Thirdly, since more female members of households in Ha-Lambani Village were water collectors, we expected that households with more female **(women)** members would demand /withdraw and use more water. The question was: Is water used at this household drawn by male members or females members?). The theory of consumer demand suggests that more women per household to collect water implies cheaper labour cost due to opportunity cost of labour as the value of time and distance spent on collecting water decreases, so we expect more water to be collected for households with more women (Banks et al.; 1997; Dawkins,1983).

Fourthly, we anticipated that households that reported that their water source produces water throughout the year **(source reliability)** to draw and use more water than those households that reported unreliability of their water sources. The question was: Is the source where you draw drinking water reliable i.e. does the source produce water all year round?). Source reliability was used as an indicator of water availability in the study area because if sources produce water all year round, then the yield was assumed sustainable in the village/area. Fifthly, households that reported that the **quality of water** from their sources was perceive good were expected to draw and use more water than households that believed that such water was of poor quality. The question was: Does the source where you draw water produce water of good quality?).

Sixthly, on the basis of consumer theory about the **influence of distance**, we expected households located further (>500m) from water sources to use less water compared to households located <500m from water sources. Theoretically, longer distances from water sources increase in real costs (time for round trip walking and waiting time) at household levels to collect such water. **Distance** in villages was captured through household survey. The question was: Is the source where you draw water for far or near? i.e. more than 500meters?). To validate such responses, we actually measured such distances using measuring tapes. Field measured results were utilised to avoid errors from under-reporting and over-reporting responses from questionnaires which could have distorted the study findings.

Seventhly, we assumed that households that knew that **water point committees** existed in the villages were expected to draw and use water more efficiently than those that reported ignorance of such committees. Committee meetings were expected to clarify water management practices and enforce water regulations. Using the argument of Swallow et al. (2006) on local institutions one sees that adoption of behaviour is a function of intent and that intention is determined by people's attitude such as expected benefits or losses, we assessed their knowledge of water point committee in their area and how such committee works to facilitate operation and maintenance of their water sources for sustainable utilization especially during drought. The question was: Do you have a water committee for this water source?).

Eighthly, we anticipated that those who know existence of **water regulations** on use and management of water sources were expected to use water more effectively than those that reported ignorance of such rules. This is because acknowledging existence of water rules would entail expectation of enforcement and compliance with such regulations thereby ensuring optimal sustainable use of water resources. The question was: Do you have regulations on the use and management of this water source?) Lastly, we assumed that safe sources of water attract more users. Hence, those who reported that safe water sources are used effectively were expected to draw and use more water from such sources than those who reported **ineffective use** of safe sources. The question was: By observing number of users, do you think people in this village use safe water sources effectively i.e. do many people use safe sources?)

4.5.3 Findings on factors for water demand and use using regression analysis

We used multiple regression analysis where SPSS software version 19 was employed for computation. First, using the coefficients, the correlation matrix showed direction and magnitude of the correlation between the dependent and independent variables for both demand and use (4.5.3.1). The best and significant predictors of demand and use of water at household in unmetered rural area were provided. Second, to ensure quality control on regression analysis model, tests of multicollinearity to check redundant variables, linearity to check outliers and normality to check normal distribution of population sample are presented (4.5.3.2). Thirdly, the full model output on multiple regression analysis showing determinants of water demand and use at household level is presented (4.5.3.3). A brief discussion on the theoretical basis for using hierarchical multiple regression analysis is provided (4.5.3.4).

4.5.3.1 The correlation matrix for estimation of the regression model

To check the best and significant predictor of water demand and use at household level in unmetered rural areas, Table 8 showed that household size was the best predictor of both water demand and water use while education variables were only significant in water demand and not water use. Predictions of dependent variables (water demand and water use) were accomplished by the following equations:

$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + ... + b_9X_9$ (Equation 1: domestic water demand)

$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \ldots + b_9X_9$ (Equation 2: domestic water use)

Where Y = Dependent variable; b_0 = constant/intercept; b = coefficient; $X_1 \ldots X_9$ = Independent variables (HHS, EDU, PWOM, SREA, GWQU, DIST, WPCO, REGU, EUSE)

Table 8:Estimating determinants of rural domestic water demand and use

Independent variables	Domestic Water demand		Domestic Water use	
	Coefficient	Significance	Coefficient	Significance
Household size (HHS)	0.330	**0.002****	0.409	**0.000*****
Education (EDU)	0.212	**0.042***	0.153	0.134
Proportion of women (PWOM)	-0.066	0.517	-0.079	0.432
Source reliability (SREA)	0.156	0.146	0.080	0.448
Groundwater quality (GWQU)	-0.034	0.746	0.039	0.708
Distance from source (DIST)	0.103	0.330	0.147	0.158
Water point committee (WPCO)	0.123	0.284	0.104	0.356
Regulations on water (REGU)	-0.018	0.879	-0.096	0.406
Effective use of water (EUSE)	0.099	0.342	0.030	0.774

***Low Significance; **Medium significance; *** High significance at 5% level.**

The variable HHs, the number of persons per household (household size), had the expected positive sign and was the only explanatory variable which was significant at 5% level in both demand and use models (Table 8). EDU variable was only significant in the demand model but not in the water use model. The rest of the variables were not statistically significant at 5% level although they had expected positive signs except PWOM, REGU in both models and GWQU in demand model. These results showed that some variables that explain water demand and use in rural areas were not captured in the current model which agrees with the observation by Mu et al., (1990) in Kenya, so these results provide a basis for further studies.

4.5.3.2 Quality control on the regression analysis

Our regression model could have suffered from multicollinearity problems because of the nature of the independent variables that were used to characterise household responses. If explanatory variables are not orthogonal, one might be a proxy for another (Mu et al., 1990). To solve the problem of multicollinearity, we calculated correlational coefficient matrix (Table 9) for the independent variables as one of the techniques for testing the presence of multicollineariy. Results showed that the data sets that were used for this study did not yield the problem of multicollinearity (Table 9) meaning there was no situation where the correlation of two independent variables was 1 or -1.

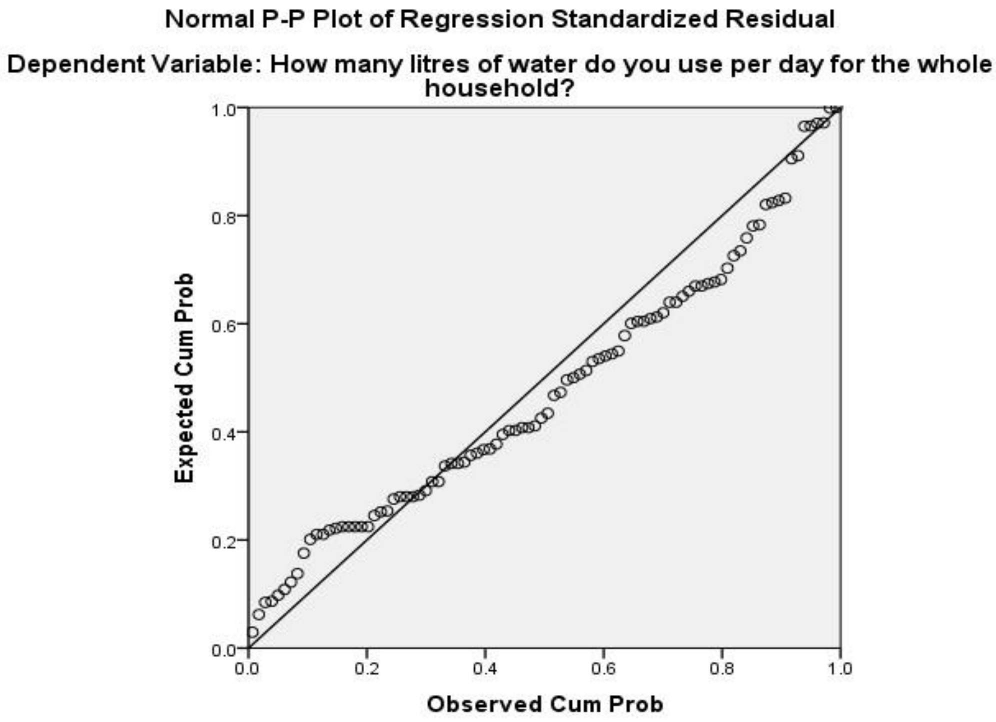
Table 9:Correlation coefficient matrix for multicollinearity

	HHSI	EDUC	PWOM	SREA	GWQU	DIST	WPCO	REGU	EUSE
HHSI	1.00								
EDUC	0.020	1.00							
PWOM	0.074	-0.020	1.00						
SREA	0.140	-0.005	0.209	1.00					
GWQU	0.055	0.046	-0.040	-0.121	1.00				
DIST	-0.060	0.261	0.030	-0.013	0.011	1.00			
WPCO	-0.129	0.088	0.008	0.141	-0.009	0.210	1.00		
REGU	0.079	0.042	-0.026	-0.032	-0.275	-0.060	-0.425	1.00	
EUSE	-0.109	-0.008	-0.120	-0.238	-0.012	-0.099	-0.009	-0.115	1.00

In this study, it was assumed that the relationships between dependent variables (water demand and water use) with independent variables (HHS, EDU, PWOM, SREA, GWQU, DIST, WPCO, REGU, EUSE) were linear. To test that assumption of linearity, a scatter plot was used. Results in the normal P-P plot of regression standardized residual (Fig 16) confirmed the linear relationship between the two dependent variables and the independent variables (predictors).

The sample population was assumed to have followed Gaussian (normal) distribution. The multiple regression computation assumed the same. That normality assumption of the sample population was tested using the histograms. Results confirmed that indeed the sample population followed Gaussian distribution pattern i.e. the sample for both dependent variables were distributed normally as displayed by the two histograms (Fig. 19) with mean = 2.34E-16, Standard deviation=0.949 and N=92. The three tests provided the confidence in the interpretation of computational output from multiple regression analyses using SPSS software (Statistical Package for Social Scientists).

In summary, to ensure quality control of the regression analysis, tests on assumptions of multicollinearity, linearity and normality were conducted and results showed no violation to such assumptions (Table 9; Fig. 18 & Fig. 19) suggesting that results from regression analysis model were reliable and valid for appropriate interpretation.



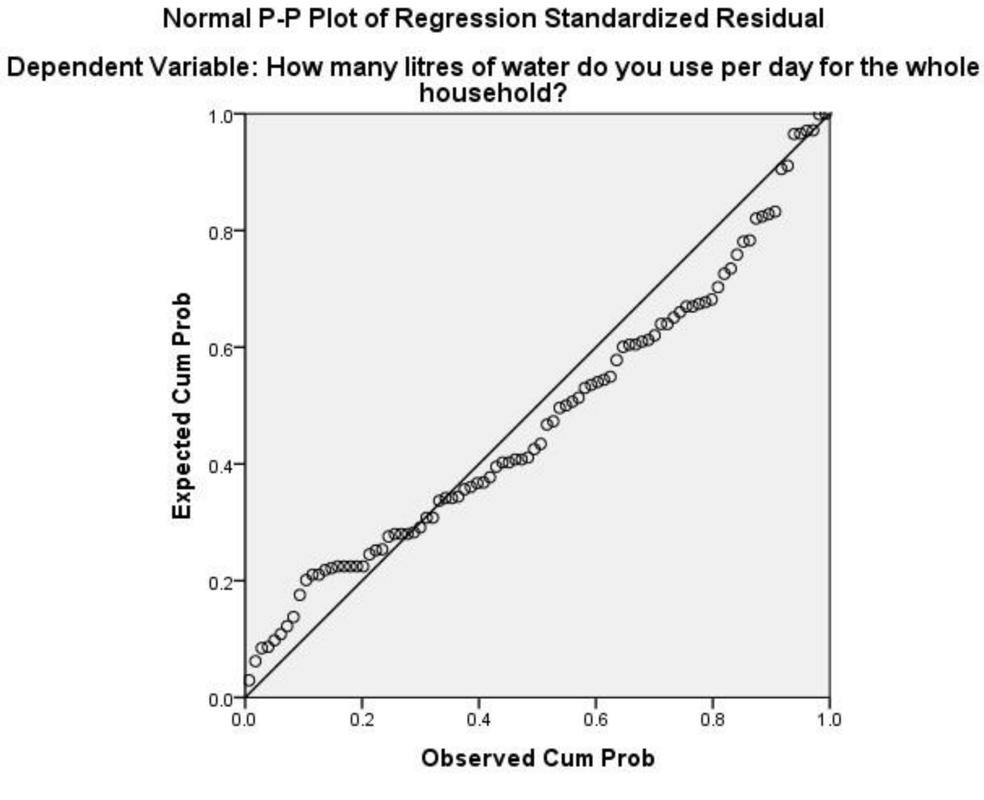
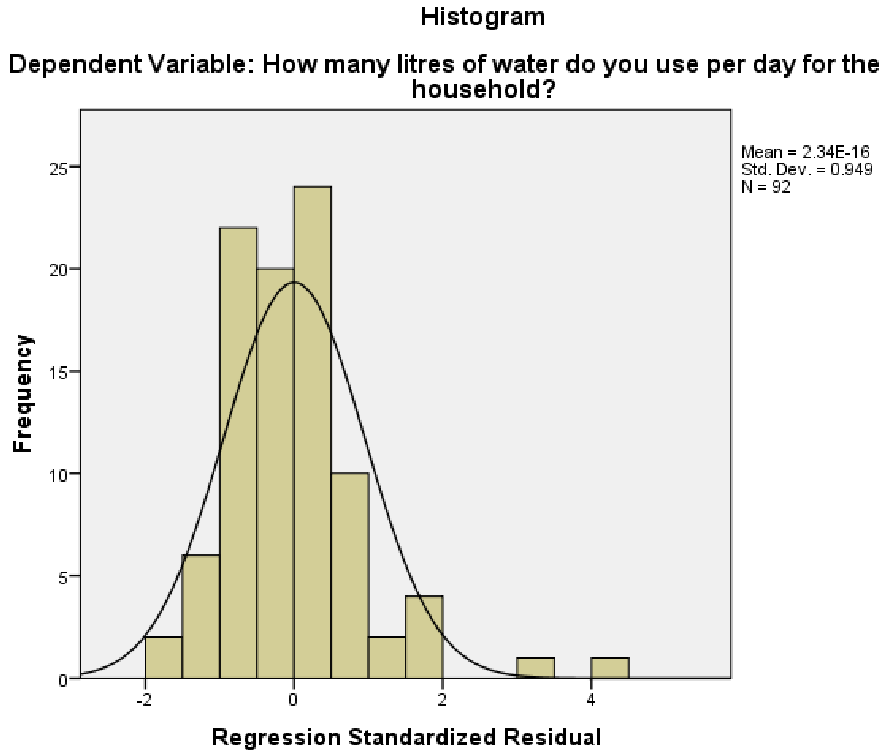


Figure 18: Results from testing linearity assumption for regression analysis



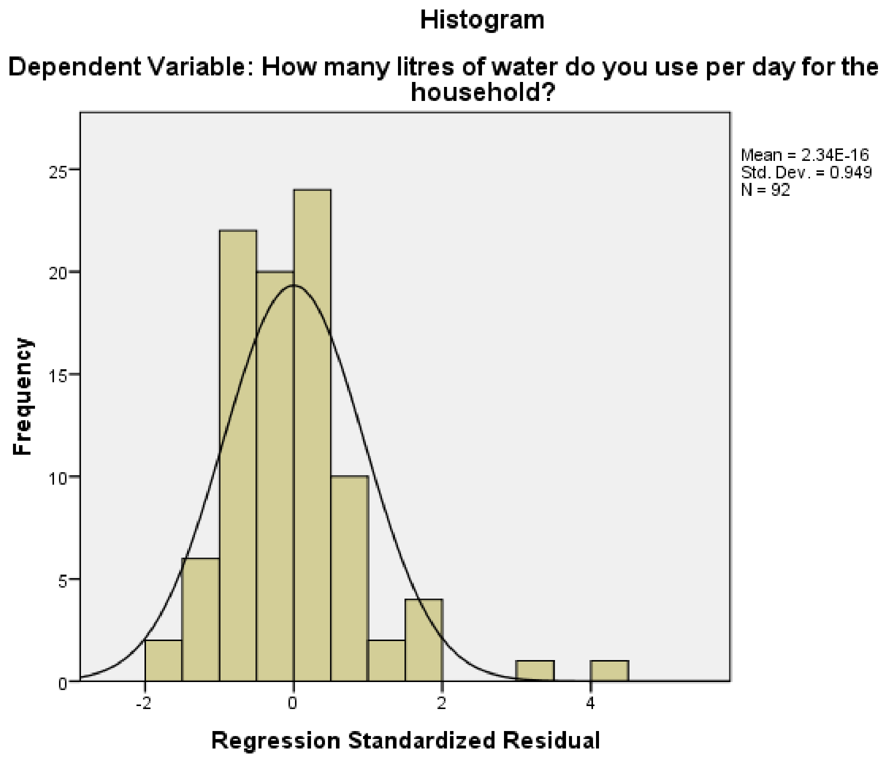


Figure 19: Results from testing normality assumption for regression analysis

4.5.3.3 Multiple regression analysis results on water demand and use determinants

The multiple regression analysis showed that the full model was statistically significant at 5% level i.e. **0.020** for water demand model and **0.008** for water use model (Table 10). However, only 12% and 15% of factors in the model explained the demand and use of water at household level respectively in rural unmetered areas as shown by the values for adjusted R squared (Table 10). The standard error of estimate column provides a rough clue on the outcome of the Adjusted R squared. Hastie et al. (2001) observed that such low adjusted R squared are usually due to a small number of variables being predicted while Dobson (1990) argued such results partly show that theoretical planning on predictors for dependent variables were weak during research design while Darlington (1990) believed that variance of some predictors result in the small observed R Squared. Agreeing with Dobson (1990) and Darling (1990), our stand suggests improving selection of parameters during research design as we acknowledge the science of uncertainty when interpreting results of a model (Good & Hardin, 2009).

Table 10:Regression analysis results on determinants of water demand and use

					Changestatistics				
Model	R	R^2	Adjusted R^2	Standard error of estimate	R^2 Change	F Change	df1	df2	Sig. F Change
1.Demand	0.45	0.21	0.12	58.02	0.21	2.36	9	82	0.020
2. Use	0.48	0.23	0.15	46.52	0.23	2.71	9	82	0.008

Predictors: HHS; EDU, PWOM, SREA; GWQU; DIST; WPCO; REGU; EUSE
Dependent variables: water demand and water use (amount of water in litres)

4.5.3.4 Theoretical implication when using multiple regression analysis

Two arguments exist on the use of multiple regression analysis. First, the hierarchical regression argues that theory should drive the choice for statistical model and the decision of specifying variables for prediction should be determined by the theoretical principles (Kutner et al., 2004). The opposing views of stepwise regression (forward and backward) argue that the data need drive the choice of variables when the statistical procedure is allowed to select predictor variables to enter in the regression equation. In this study, the hierarchical regression was adopted because of theoretical principles. However, several forward and backwards procedures were applied to the model which produced different outputs. Stepwise gave no guarantee that outputs from forward and backward processes would converge on single regression model when combined which confirmed results by other scholars

(Darlington, 1990; Anderson, 1984; Cleveland, 1983). Therefore, the full model was selected and applied in this study although it was expected that the accuracy of prediction would be weakened due to variances (error) within the data sets which generally affect regression procedure. The greater the error in the regression procedure, the greater the shrinkage of the value of R squared which is common to prediction models such as regression (Good & Hardin, 2009). However, regression models remain powerful methods to analyse multivariate data and this is the reason why in this study we opted for the use of the multiple regression method (Freedman, 2005). In this study, the theory based on our research question informed the choice to use multiple regression and assumptions were cross-validated for better interpretation (Chiang, 2003). But the reality on the science of uncertainty might have weakened our interpretation.

4.7 Implication for water governance and management during drought

Since methods to provide quantitative data on groundwater availability continue to be scarce (MacDonald et al., 2012), then our qualitative approach for assessing groundwater availability as used in this study was probably the only way to obtain accurate results on providing a crude estimate on groundwater availability and such information can contribute to design implementation plan for good governance of groundwater especially in the context of drought. Although the approach is qualitative, it uses scientific principles and provides explanations that seem easily understood by all stakeholders actively participating governing, using and managing water resources in rural areas with environments similar to our study area and beyond. Above all, the understanding among water stakeholders on the influence of the factors that explain groundwater availability at catchment level has positive potential influence on bringing all the stakeholders together for a successful implementation of good local groundwater governance practices especially in the vulnerability context of drought.

Results on calculation of water demand and use per person per day, per household per day and per sub-catchment in an unmetered rural area appeared realistic and practical. However, the method used to obtain the amount of water withdrawn (demand) and used at each sampled household was rather time-consuming because it required actually measuring the amount of water from each households containers into our research calibrated 20-litre plastic bucket and visiting each sampled household early in the morning before that household started drawing fresh water for that new day. Thereafter, all the recorded values from field notebooks on water demand and use for each household were separately entered into SPSS for analysis to obtain average water demand and use. Then the average figure was multiplied by the total number of the households to find water demand and use for the sub-catchment and then divided that average household figure by household size to find water demand and use per person per day. This was done separately for demand and use. Despite being time-consuming, the approach was probably the only way to obtain accurate results which were similar to those obtained when using the Wallingford (2003) approach. A drawback on our approach is that it can be used only in unmetered rural areas on the assumption that no taps and pipes are connected in households. Thus, with such fewer computational steps compared to those of Wallingford (2003), the proposed approach provided one step towards facilitating a designing a successful implementation plan for good local governance for groundwater thereby forming a platform for collaborative efforts among stakeholders.

On factors that affect demand and use of water, results showed that number of persons per household (household size) influence both demand and use while education was only significant in the demand model but not in the water use model. These results are consistent with various studies which revealed that population is the main drive for demand and use on water. Although the influence of weather (seasonality) on water demand and use was not tested, results would have shown that a declining rainfall pattern as has effect on water demand and use. These statistics provide useful insights and platform towards lobbying execution of an implementation plan for rural communities where water managers, users, developers and water scientists would use such results to enforce collaborative efforts.

4.8 Summary

This chapter has fulfilled the objectives 1, 2 and 3 on water availability, demand and use. The detailed summary on this chapter is provided in section 4.7 where implications for designing implementation plan drew on the provided key results in the same section. In this chapter factors that explain availability, demand and use for groundwater have been explored. By using physiographic factors groundwater availability has been assessed qualitatively and such assessment has improved the understanding for key stakeholders" input with regards to governing and managing water resources at village level. This study has confirmed the water scarcity situation in Ha-Lambani Village which was not a surprise because the studied village is in semi-arid environment and in South Africa, a physically water scarce country. Therefore, lobbying for the design of an implementation plan for good governance and management of such water resources is the most viable and rational action plan for sustainable utilization of such waters especially in the context of drought events.

The present investigation vindicated that the use of the proposed approach on calculation water demand and use in unmetered rural environment, though time-consuming provides a basis for providing systematic data that can inform a quantitative understanding among key water stakeholders for implementing action plan at sub-catchment level. The detailed statistical computation used in this study and discussion on its strengths and weaknesses provides enlightenment on interpreting results from such method thereby proving opportunities for further researchers to refine the methodology. The systematic computational procedure provided is a major step towards a more informed procedural assessment approach on data generation and its implication for managing water in a coordinated manner in the communities especially in rural unmetered communities.

As a showcase study, findings from the Ha-Lambani Village demonstrated procedures that were followed to generate statistics on demand and use of rural domestic water at household level. Such results highlighted evidence-based guide on how to generated statistics need to guide the design of implementation to promote local groundwater good governance practice. The assessment on determinants of demand and use of such waters contributed to a comprehensive assessment of factors that explain the key drivers for observed abstraction and consumption of groundwater in the study area. The assumption is that generation of statistical estimates contributes towards decision making in term of the appropriateness of the implementation plan for water utilization and management practices. To make audacious statements on local good governance of groundwater, statistics need to be provided on the volumes of water abstracted and consumed that are observed being in communities. Such quantitative assessment forms the basis for evidence on the needed confidence for promoting local governance and management of water resources especially during droughts events.

CHAPTER 5: IMPLEMENTATION PLAN FOR LOCAL GROUNDWATER GOVERNANCE FOR RURAL DOMESTIC WATER DEMAND AND USE

5.1 Introduction

This chapter presents and discusses results on objective 4 which explored appropriate implementation plan for local groundwater governance using Ostrom design principles of good governance for domestic water demand and use. The results and discussion in this chapter answered the research on the appropriate implementation plan that is required for local groundwater good governance practice. The argument in this chapter is that a plan that considers local context would be ideal to implement local governance practice for sustainable management and utilization of groundwater especially during drought events. Field observation, interviews, records review, interpretative methods and analytical methods were used to collect and analyse data to inform a discussion on groundwater good governance as an intervention during drought in rural unmetered areas. The analysis in this chapter provided a basis for designed, presented and discussed implementation plan which is thought appropriate for practicing good governance at local scale in the vulnerability context of drought. Therefore, this chapter answers the main research question, the main research hypothesis and addresses the main study objective (study aim) as presented in chapter1.

5.2 Assessment of local level governance: Thematic-content analysis

In this section, 5.2 findings from field observations, focus group discussions (FGDs) and key informant interviews (KII) are presented and thematic-content analysis was used to assess some aspects of local level governance for groundwater demand and use in the study area. The analysis provided in this section (5.2) is brief but it has formed the basis for detailed discussion on local groundwater governance in Ha-Lambani Village in terms of the analytical framework for provisions and institutional arrangements (section 5.3) for good local groundwater governance practice; application of the Ostrom design principles (section 5.4) for good local groundwater governance; and the required implementation plan (section 5.5) which is considered as appropriate for the vulnerability context of drought in rural areas.

Some of the households

Limbedzi secondary school

Ha-Lambani Clinic

Triple K Restaurant

Figure 20: Some of the institutional arrangements for local groundwater governance (Photo: Lebese;2014)

Fig. 20 shows some of the institutions for local groundwater governance provisions and institutional arrangements. Such institutions were analysed for domestic water demand and use in Ha-Lambani village which includes households, schools, health facilities and private business facilities (Fig. 18). The facilities used public as well as private water sources. These facilities have storage tanks such as green jojo tanks for water storage. The analysis of water storage was outside the scope of the present study therefore such issues were not discussed. However, the aspect of selling water from private boreholes to community members at R2 per 25 litres has implication for good governance which is discussed in sections 5.3;5.4 and 5.5 of this thesis. However, the water from public boreholes, open well and community taps are provided for free to people in Ha-Lambani. Governing and managing such water sources during drought events require good governance provisions and institutional arrangements alongside appropriate implementation plan as discussed in 5.5.

Public water point taps (community taps)

Public boreholes without a tap

Open well from a fountain

Private borehole with a tap

Figure 21: Some of water sources which are used during draught events (Photo:Lebese;2014)

The present study showed the availability of various sources of water that were used during drought events (Fig. 21) in addition to Luvuvhu River. Not all households have access to the available sources due some rules associated with certain sources as shown in section 5.4. It was reported that 12 public boreholes (BHs) were not working since the 2000-flush flood in the study area and since then, no public institution assisted the community on such BHs.

Koatla (2014) reported that institutional arrangements are vital to enforce ownership of the infrastructures that protect water resources and that all water users need to adhere to rules set up by the institutions and implement such rules. The present study used analytic framework to analyse local groundwater governance institutional arrangements and application of Ostrom design principles in order to propose an implantation plan for local groundwater good governance for sustainable rural domestic water demand and use especially during drought.

The following quotations were obtained during the field observation and interviews which have formed the basis of the detailed discussions in sections 5.3; 5.4 and 5.5 of chapter 5.

"Our school rely on boreholes water especially during drought. We have Jojo tanks for rain harvesting during rainy seasons. We also get water from public taps. "I look after the school and I make sure that the water tap is closed when not in use" (*Personal communication 1*)

"No restrictions and rules exist for accessing water from community taps, boreholes and fountains. These water sources belong to all of us and no one has put rules, we all use these sources whenever we want. However, since I stay near the open well, I prevent animals from making water dirty. So I protect it with some tree-thorns so that goats and dogs do not use it"

(*Personal communication 2*, a woman and members of farmer association, 2014).

In rural villages, the most common use for domestic water comprises indoor use such as drinking, cooking, cleaning, laundry and bathing whereas outdoor use include livestock watering, garden watering and yard cleaning (Fan 2013, Jorgensen 2009 and Keshavarzi, 2006). These uses were also found in Ha-Lamabani, but the present study was not about the details of how water is used but how much water was abstracted and consumed at household level. Thus, discussion on details on what water was used for is not pursued in this chapter.

5.3 Analytical framework for local groundwater governance

Governance provisions at local level for the study area appear to be to be insufficient to deal with the prevailing drought events, even though there are some provisions. However, implementation and capacity seem to be lacking in many area including Ha-Lambani Village. Table provides analysis of governance provisions and institutional capacity at local level for water demand and use using a framework developed from the 20 benchmarking criterion by Foster et al., (2010). The collected data analysed using the developed framework combined the thematic and content analyses. Further, the table makes use of codes to provide a better analysis of the data collected; 0 = non – existent, 1 = existence, 2 = good, and 3 = excellent.

Table 11:Local groundwater governance provisions and institutional arrangements

Capacity	Context	Criterion	Provision	Institutional Capacity
Technical	Baseline measurements and continual monitoring Programs	To detect groundwater pollution	0	1
		To determine resource status	2	1
		Protection of water resources	2	2
	Licenses	Setting conditions	2	2
		Review of licenses	0	0
		Use of alternative water sources	3	3
		Management of Water Use	2	2
		Water balance	0	0
	Prevention of pollution and / or over-abstraction	Mitigation options in place	1	1
		Managing water demand/abstraction	3	3
		Management of pollution (Open well)	0	0
		Report on water use or water abstraction	0	0
Legal and Institutional	Transgressions	Dealing with non-compliant users	1	2
		Mobilizing and formalizing community participation	3	3
	Empower to act on cross-sectorial basis	Setting-up water management institutions to deal with water demand and use	1	3
Cross-sector Policy Coordination	Ensure „real water saving" and pollution control	Government agencies as groundwater resource guardian	1	1
		Good governance in place to control water demand, use and pollution	0	0
	To enable access to public information	Coordination with domestic and agricultural development	1	2
		Freedom of information and transparency	2	1
Operational	With measures and instruments agreed	Public participation in groundwater management (meetings)	1	1
		Existence of groundwater management plan (Plans were absent)	0	0

Governance provisions at local level for the study area appear to be to be insufficient to deal with water demand and use, even though there are some provisions. Implementation and capacity seem to be lacking in many areas as shown in Table 11. However, table….provides analysis of good governance for provisions and institutional capacity at local level for groundwater availability, demand and use using a framework developed from benchmarking criterion by Foster et al (2009). The collected data was analysed using the developed framework combined with thematic and content analyses. Further, the table makes use of codes to provide a better analysis of the data collected; 0 = non – existent, 1 =existence, 2 = fair, and 3 = excellent (adapted and modified from Foster et al., 2009).

With Limpopo Catchment management agency (CMA), a baseline measurement of groundwater and continual monitoring program within the study does exist, but only for determining groundwater resource, and that only occurs within the municipal well fields of Thulamela local municipality but not in Ha-Lambani Village where private groundwater sources exist and are abstracted. Further, communities in Ha-Lambani are responsible for protecting and managing their groundwater resources. It was noted that the Vhembe district municipality and Thulamela local municipality do not have adequate capacity in terms of highly skilled professionals such as hydrogeologist, as they only have engineers to deal with all issues around water resources, unless outsourced.

The minister of Water and Sanitation has delegated the Limpopo Catchment Management Agency (LCMA) to deal with all water user license applications through the National Water Act (Act of 1998). However, at present, the Limpopo CMA does not have adequate knowledge and understanding of groundwater availability, demand and use in the catchment (DWA, 2015). In addition, the current requirements in water-user license do not address the issues of rural domestic water demand and use at village, local scale. Therefore, such requirements like amount of water abstracted and used by each household, does not exist. However, more work on water allocation where issues of water demand and use will need to consider water-user license. Further, use of alternative water resources is also suggested in the license application, but currently, the area has limited water resources, depending mostly on groundwater as described in chapter on factors that influencing water availability.

Note that since 2004, the Netherlands and South Africa share knowledge in the field of decentralization of water management and the political and strategic aspects of water management. This exchange is now confirmed with an official cooperation in a strategic agreement. Van Haersma Buma (personal communication, 2015): “There is a big difference in the practice of water governance in both countries. At the same time, we face similar issues, such as organization, financing, legislation, enforcement, public participation and knowledge transfer”. South Africa’s water governance structure is currently being reorganised which involves the decentralisation of tasks from the Department of Water Affairs (DWA) to Catchment Management Agencies (CMAs). By the end of 2015 nine CMAs were established (Fig. 22). The joint Dutch-South African Kingfisher program supports this development by providing Dutch’s expertise from water authorities and municipalities. The CMAs will play a critical role in managing the country's scarce water resources, including facilitating stakeholder input for managing water resources such as groundwater especially during drought events.

Figure 22:Nine Catchment Management Agencies for water management in South Africa

The present study has shown that currently, no mitigation options exist in Ha-Lambani Village for groundwater pollution as there are no major threats on groundwater from activities such as industrial, discharging of untreated effluent or mining activities. Therefore, to be able to govern or manage groundwater demand and use, there will be a need to have an implementation plan in place that considers aspects of good governance practice. Such plan will require a monitoring and evaluation plans to ensure that good local governance for groundwater demand and use are operational for sustainable use of the resources.The present study found that the groundwater institutions within Ha-Lambani Village have no measures in place for management of water from boreholes, open well, community water tap and nearby Livuvhu River. It was revealed during the FGDs and KII there are proposals to develop such mechanisms especially during drought events period.

The NWA (Act no 36 of 1998) provides provisions, measures and a good regulatory system for water resource protection. However, the NWA lacks appropriate implementation. The present study found that there were partial community involvement regarding protection of groundwater resources, but the CMA believes that people's negligence to participate in groundwater management is caused by lack of water issues. However, the Thulamela local municipality and Limpopo WMA believe that when awareness about groundwater resource is promoted, people will mobilize towards groundwater protection especially during drought events. The study found that existing water management institutions within Ha-Lambani Village ranged from School committees, Farmers clubs/groups, local municipality, district municipality, catchment management agency, provincial government among others. However, South African waters are controlled, managed and protected by the Department of Water and Sanitation (DWS). In addition, the minister can delegate certain duties to the CMA which include water user application, management of water resources at catchment level among others. Even though these responsibilities are delegated to CMAs, the final decision is still made by the DWS, making managing of water resource at local scale problematic.

The roles and responsibilities of the institutions present within the study area were not clearly articulated during the study. Further, the local municipality within the study area is responsible for bulk water supply service but not activities such as water demand /abstraction /acquisition from groundwater sources and activities associated with the usage of such waters. In addition, some local municipality including Thulamela, struggle with their roles and responsibilities several factors including budget cuts to implement and strengthen regulations (Pietersen et al., 2011). Therefore, it is recommended that local institutions in villages be established and empowered to deal with good governance of water demand and use aspects for sustainable use. In addition, the study showed that coordination between water users such as agriculture, stock farming among others in Ha-Lambani Village was not adequate as a result some households were responsible for drilling their own wells to access groundwater and monitoring of such wells because it was said that Thulamela Local Municipality was providing communities in Ha-Lambani with running water through communal taps.

The study found that public participation for groundwater management in Ha-Lambani Village was minimal. This was surprising because with the prevailing drought, it was thought that the public would feel obligated to manage or protect groundwater resources. In addition, it was expected that groundwater management plans would be available in the offices of Thulamela Local Municipality for areas such Ha-Lambani Village, such plans were absent. Hence the argument for the present study that an implementation plan to promote good local governance practice for groundwater demand and use in the study area is essential and that such a plan would ensure protection and management of groundwater. The scholarly work has shown that roles, rights and responsibilities of people within communities are socially defined, culturally-based and are reflected in formal and informal power relations that influence how management decisions are arrived at (UNDP, 2008; Molden, 2007). Water management and all other activities related to it have an impact on social interactions and structures. Understanding social dynamics in water management requires strengthening or adapting existing social stratifications to water management interventions. Hence the need for an appropriate implementation plan that needs to consider aspects of such institutions.

5.4 Application of Ostrom design principles of governance

This section presents findings on the application of the Ostrom design principles for governance in the context of groundwater resources at local village level during drought events in Ha-Lambani Village. Further, the discussion highlights some reported limitations of the principles regardless of empirical evidence of successful application of such principles in many areas as presented in Chapter 2 of this thesis.

Table 12:Application of Ostrom principles to local groundwater governance in Ha-Lambani

Keys aspects of Ostrom design principles	Application of principles in Ha-Lambani	Comments on applicable aspects of the design principles in Ha-Lambani Village
Principle 1: Well-defined boundaries around resource system in communities	Yes, it was applicable as water sources had boundaries	Water sources: BHs, Open Wells, community taps and river had well-defined physical and socio-cultural boundaries and associated rules on using such resources
Principle 2: Congruence between appropriation and provision rules and local conditions	Yes, it was partly applicable	Ownership of water sources and associated rules on looking after and using such resources were partly reported to exist and there were more similar to principle one.
Principle 3: Collective-choice arrangements	Yes, it was applicable and confirmed during FGDs	During FGDs, it was clear that operational rules are discussed and agreed upon among users of the resources in the village
Principle 4: Monitoring	Yes, it was applicable and confirmed during field observation	During field observation, it was confirmed that the schools board assigned one person from the same village to look after BHs at school
Principle 5: Graduated sanctions	No, this one was not applicable	During FGDs and KII, it was reported that they do not like punishments but encouragement for deviants or defaulters
Principle 6: Conflict resolution mechanisms	Yes, it was applicable and confirmed at FGDs andKII	FGDs and KII revealed the existence of measures to manage conflicts such as committees and the Chief sometimes

Principle 7: Minimum recognition of rights	Yes, this one was applicable	BHs at school drilled by government, and community tap by local municipality but these are governed and managed by school committee and community committee
Principle 8: Nested enterprises	Yes but it was partly applicable	It was same like in principle 7 where there were some agreements between community members and providers of someservices

The present study had shown that the design principles of Ostrom are relevant and applicable in Ha-Lambani Village with regards to water resource governance at local level. These findings are in agreement with the reviewed scholarly work presented in the Chapter 2 of this thesis and will not be repeated in this present chapter (chapter 5). However, the identified three primary critiques directed at the design principles as a whole are discussed in the present chapter to highlight areas of improvement in applying such principles.

Some scholars argue that design principles are incomplete, and many studies suggest additional criteria for sustainable management of natural resources such as water. Some scholars argue that critical social variables need to be included in a full account of successful community-based natural resource management. Singleton and Taylor (1992), for example, argue that the more fundamental features of the successful systems in Ostrom's (1990) study is the quality that each involves a "community of mutually vulnerable actors." Singleton and Taylor (1992) view these conditions explain why some communities are able to fulfill the design principles and sustain themselves while others are not. In another example, Harkes (2006), who studied marine sasi fishery systems in Indonesia, states:

The design principles of Ostrom (1990) and other scientists who have pursued this line of thinking thus are an interesting point of exit, but only partly explain the success of management institutions. Most of the conditions mentioned are merely characteristics of the community or institution, such as scale, village size, homogeneity, or the ability to exclude outsiders, and even though these factors undoubtedly contribute to their functionality, from our study it has become clear that the real „glue" that keeps an institution alive over time are the social mechanisms, i.e., trust, legitimacy, and transparency.

The present study in Ha-Lambani Village has also shown that the principles are incomplete meaning not all principles were applied and some applied partially. This suggests that there were other features in communities that affect outcomes when CPRs are managed by communities of users. Therefore, we should not only be considering local-level institutional properties because local and external socioeconomic factors matters as well. However, this critique does not weaken the empirical support for the principles as presented in Chapter 2. Secondly, it has been argued that design principles may not be applicable to a wide range of cases beyond those that were used to develop them. For example, Pomeroy et al. (2001); Young, (2002); Berkes (2005 & 2006) question the applicability of the principles to cases larger in scale than those from which Ostrom (1990) derived them. Berkes (2005) states that globalization has a major impact on local-level resource management through such mechanisms as the creation of international markets. Therefore, Berkes (2005) argues that a theory of the commons that is based on local-level cases cannot be scaled up to deal with the complexity of communities and social-political networks, a view which Young (2002) opposes and the present study agrees with Young's idea that Berkes thoughts need reflection

Agreeing with Rowland (2005), findings in Ha-Lambani Village has shown that it seems plausible that several of the principles would be applicable to higher levels of governance (Rowland, 2005). For example, proportionality of costs and benefits, conflict-resolution mechanisms, nested institutional arrangements, and effective and participatory collective-choice arrangements seem particularly relevant. The applicability of the design principles to a higher level of governance is not a claim that communities can necessarily resolve large-scale environmental problems (Rowland, 2005) but that context matters as stated by Ostrom 1990.

The third critique, criticizes what it conceives as the design principle approach itself. Several authors argue for a more constructionist or historically, socially, and environmentally embedded perspective that departs from viewing actors as rational decision makers, and communities of users as coherent wholes without internal conflict or heterogeneity (Mosse 1997; Leach et al., 1999; Klooster, 2000). Others authors suggest that the design principles are biased toward formal rules and strategies and may abstract too much from the complexity of the environment and the social context of the actors (Steins 1999; Steins and Edwards 1999; Cleaver 1999, 2000; Blaikie, 2006). Related to these arguments is the general concern that the principles might be seen as something of a magic bullet or institutional panacea and thus be misapplied as a prescription for improving the governance of CPRs in particular settings (Bruns 2007). This concern is about the possible overgeneralization of the principles to a large diversity of cases, the individuality of the institutions are not sufficiently reflected.

This issue of theoretical generalisability and the tension between it and theoretical precision is too large to be treated adequately here. Cox (2008) describes the trade-off between generalisability and precision that Ostrom (1990) made in her formulation of the principles.

A concern about implementing a set of possibly over generalized design principles is analogous to that raised by Hayek (1945) and Scott (1998): that a government may fail by homogenizing the diversity of contexts to which it applies its policies and management practices. This is sometimes referred to as a blueprint approach to governance, which leads to a lack of fit between programs and their supposed beneficiaries (Korten, 1980). In effect, there is a concern that such application of the principles may violate principle 2A of design principles which state that congruency between rules and local conditions need consideration.

Young (2002) contrasts the design principles approach with what he calls a diagnostic approach to analysis. He states, "Because design principles are framed as universal propositions, they should hold across all members of the relevant universe of cases" (Young, 2002). Agrawal (2002) makes a similar argument that the principles "are expressed as general features of long-lived, successful commons management rather than as relationships between characteristics of the constituent analytical units or as factors that depend for their efficacy on the presence or absence of other variables." In lieu of the design principles approach, Young (2002) favours a diagnostic process of subdividing environmental problems into subsets to tease out the institutional implications of different types of environmental problems. Indeed, Ostrom (2009) is moving in a diagnostic direction as well. She states, "We need to recognize and understand the complexity to develop diagnostic methods to identify combinations of variables that affect incentives and actions of actors under diverse governance systems".

Ostrom continue to argue that, "although we think that there are likely limitations in generalizing the design principles to larger-scale cases, we argue that the dichotomy between diagnostic and design principle approaches is false, at least in this context. A diagnostic approach most fundamentally involves two tasks: identifying an environmental problem, and identifying the governance arrangements that are most likely to be effective in resolving that problem. To do this most effectively, one needs to construct nested typologies of environmental problems and governance arrangements. If this can be done, it may be possible, with accumulated empirical evidence, to match types of governance arrangements to types of problems that they have proven to be effective in resolving". A nested typology contains types that are arranged hierarchically, with each level being a subdivision of types from the previous level into further subtypes. The present study in Ha-Lambani village considers these criticisms as a basis for conducting a more detailed study with refine study design to capture as many variables as possible for detailed and thorough analysis to address most of these criticisms. Such approach was beyond the nature and scope of the present study. In summary it can said that the design principles of Ostrom were found applicable in Ha-Lambani village (Table10).

5.5 Implementation plan for local groundwater governance

The section presents an implementation/action/operational plan with activities and methods that aim at promoting good governance for groundwater at local level using Ha-Lambani Village as a case study. Based on the prevailing situation in Ha-Lambani Village, the immediate action is to conduct detailed field observations and consultative meetings with all stakeholders (organisations, clubs, committees, individuals) in Ha-Lambani community in addition to relevant officers for Thulamela Local Municipality and Vhembe District Municipality and Limpopo Catchment Management Agency on groundwater governance and management. This approach is appropriate as it considers all stakeholders in the process of designing a real bottom-up participative and inclusive implementation plan that draws on many resources, many views in a more participatory, equitable and holistic manner and provides a platform to mediate for coordinated action by all the concerned parties.

The vision/aim for the implementation plan is to have Ha-Lambani Village where a responsive, sustainable groundwater system, through collaborative efforts among stakeholders, that has a broad focus on design principles of Ostrom regarding good local governance is positioned to respond to water challenges including rural domestic water demand and use, and protects water and promotes the well-being of Ha-Lambani people. With the increasing effect of climate variably on water resources, having such an action plan for groundwater resources has multiple benefits as surface water continues to dwindle (FAO, 2010). Details on impact of climate variability on water resources are provide in Chapter2.

The increasing insufficient of budget to spend on various interventions in the water sector does not show sign of abating (FAO, 2010). Therefore, there is a need for action plan that would lobby for improved resources and capacity in institutions that would promote good local governance to increase access to groundwater that would strengthen the resilience of communities during drought events (UNESCO, 2014). Such action plan would be operationalized through four objectives as follows: i) lobby for provision of more improved reliable sources of clean water supply to strengthen adaptive capacity of communities during drought events; ii) facilitate creation of clubs and committees in communities that would provide supportive environment for community members to explore behaviours and practices that promote local groundwater governance; iii) Lobby for creation of intersectoral committees that would strengthen community action on measures that promotes local groundwater governance in rural area such as Ha-Lambani Village; and iv) facilitate engagement of stakeholder such as volunteers and leaders to organize people for drama sessions and to organize volunteers to distribute posters in public places using community participation and media strategies in order to strengthen awareness (civic education).

The implementation plan will require the use of four strategies as follows: 1) Intersectoral collaboration whereby communities receive immediate information and feedback on procedure for enforcing the local groundwater governance resulting in better decision making. Secondly, sectors share investment and personal skills as they work together thereby producing most coast- efficient solutions for water management. This enables sectors to deal with water issues before they become a problem (Ramduny, 1998). Thirdly, different sectors know activities of each other thereby reducing duplication of activities, conflict and competition thereby saving resources (WHO, 1998). Fourthly, sectors work in a coordinated mannerthatprovidesasupportiveenvironmentresultinginretainingrelevantstakeholders;

2) Media strategy will be used for the action plan through radio, posters, door-to-door campaign and theatre-for-development (drama) depending on appropriateness, accessibility and affordability of such media types. The aim will be provide effective, sustained and persuasive communication that makes communities stay engaged with local groundwater governance practices (Krueger, et al., 2000; WHO, 2008; UNICEF, 2009).

3) Community participation/stakeholder engagement which has five benefits as follows: First, communities acquire greater control over their own resources thereby becoming responsible to promote practices that would promote the required governance. Secondly, communities assess their own needs thereby improving their skills to list what they want then prioritize the most urgent needs. Thirdly, communities suggest their own solutions meaning that after

prioritizing their needs, communities suggest better solutions depending on resource availability. Fourthly, communities are empowered to influence their infrastructure, technology and personnel of water management thereby being able to make decisions on how to improve their water governance. This creates social change by building advocacy skills and empowers communities. Fifthly, communities become more aware that stakeholder engagement takes time when they are part of the process thereby owning the process and its benefits thereafter (Person, 1996; Ostrom 1990; FAO,2010).

4) Settings approach will be used for action plan from local groundwater governance perspective because it provides a focus for local action across a diversity of environmental risk factors thereby facilitating a holistic approach to improve the setting where people spend their lives such as water demand and use facilities in Ha-Lambani community. Secondly, it provides a channel and mechanisms of influence for reaching a defined population group and involving frequent and sustained interactions and communication between groups through lobbying actions.This creates efficiencies in time and resources and offers more access and greater potential for social influence. Setting approach is adaptive to different locations and conditions and thereby providing effective channels of communicating various messages. For example, in communities, water setting approach allows the mobilization of community leaders to champion the necessary action and the creation of mechanism for participatory action by community groups (Coulson et al., 1998). It is multi-disciplinary and cross sectoral in its orientation; recognizes the effect of environmental and structural factors in communities; focuses on policy, organisations and communities in its operations with respect to local, regional and national politics to community activities among others (Coulson et al., 1998 & Baum, 2008) thereby fulfilling design principles of Ostrom and key aspects of good governance for groundwater in local areas especially during drought events.

Sprechman and Pelton (2001) define advocacy as an active support of an idea or cause expressed through strategies and methods that influence the opinions and decisions of people and organisations. In the proposed implementation plan, the advocacy will operate through the four strategies and methods as described above where intersectoral, community participation, media and setting strategies will be included. Advocacy aims at creating or changing policies, regulations, distribution of resources or other decisions that affect people's lives and to ensure that such decisions lead to implementation of activities that promotes local groundwater governance in communities. In general, advocacy is directed at policy makers including politicians, government officials and public servants, but also private sector leaders whose decisions impact upon people's lives, as well as those whose opinions and actions influence policy makers, such as journalists and the media, development agencies and large Non-governmental organisations and even small clubs and organisations in communities. The advocacy strategy will target various target population as provided in section below.

The implementation plan in a tabular format outlines its objectives, activities, process, responsible person to implement activities, advocacy activities, target population and evaluation indicators (Table 12). Based on the findings in Ha-Lambani Village, it is viewed that proposing an implementation plan is the key to successful operation of local groundwater governance aspects that aim at improving communities capability, resilience and coping mechanisms during drought events. The use of evaluation indicators ensures that the action plan will be checked to assess its progress regarding improvement on local good governance for groundwater so that necessary modifications can be made to achieve the goal.

The implementation plan has four objectives as described above and presented in Table 12 This section provides an evaluation on the action plan with the aim of assessing whether or not a) the objectives have been met using the planned activities and b) whether or not the Ostrom design principles and key aspects of good governance for groundwater will be met using the planned advocacy strategies and tasks for different role-players.

Objective 1: By engaging stakeholders such as politicians and government officials to provide funds for construction of water facilities and by requesting community leaders to ensure that community policing committees protect facilities from being vandalized, it means there will be intersectoral collaboration, community participation and stakeholder engagement in the process of lobbying for the provision of improved water facilities and more sources of clean water supply. This means that the first (1) objective will be met. Conducting field visits with stakeholders to observe and inspect water facilities and water supply sources will enable the settings approach to show stakeholders physical environment that creative supportive conditions for water availability. The inclusion of politicians, municipality officials, catchment officials, community leaders working together on one water issue fulfills the participative, holistic, intersectoral and empowerment principles whereby members from political, civil and community will take active role in making decisions about the people that needed water during drought. Such a process facilitates the provision of water. The process provides supportive environment for community members to explore measures of sustaining the water facilities by ensuring that community policing committees adopt strategies that protect water facilities from being vandalized (Ruddle 1996, Cleaver 1999, 2000, Turner 1999, Mandondo 2001, Blaikie 2006). Cleaver(1999)

Objective 2: By recruiting stakeholders such as volunteers and leaders to facilitate meetings and by involving community leaders such as religious and traditional leaders alongside civil servants working in the communities using community participation (stakeholder engagement) to create clubs and committees in communities, it means community participation operates or exists. This means that objective two (2) on facilitating creations of clubs and committees in communities was achieved because there was community participation. In addition, the participative and empowerment principles of governance is then fulfilled whereby community members will take active role in making decisions about the

Objective 3: By involving representatives from different organisations such as government departments (municipality and catchment management agency) and Non-Governmental organisations working in the study area for a meeting to form intersectoral committees, it means that there will be intersectoral collaboration thereby achieving objective three (3) on creating intersectoral committees in Ha-Lambani area. This shows that the intersectoral and holistic principles is fulfilled whereby stakeholders from different organisations will come and work in partnership and contribute different ideas in an interaction manner which will enable creation of such committees with the aim of improving local governance for groundwater in communities. Through such holistic and intersectoral approaches, committees will develop and sustain personal skills to enable them raise awareness and advocate for water policy reform in their areas that support their water-related initiatives considering their vulnerability context of drought and rural area setting.

Objective 4: By engaging stakeholders such as volunteers and leaders to organize people for drama sessions and to organize volunteer to distribute posters in public places using community participation (theatre-for-development i.e. drama) and media such as posters in order to strengthen awareness (civic education), it means there will be community participation, stakeholder engagement and intersectoral collaboration. This means that objective four (4) will be achieved. In addition, the multi-strategies, equitable, participative and intersectoral principles will be fulfilled whereby posters and drama and meetings will be used for civic education in Ha-Lambani community and where by community members will participate during drama session through feedback slots. Such a process will further empower the community and developed personal skills to participate in decisions making (feedbacks) as the drama progressed thereby strengthening community members to take active role or action regarding initiatives and information that are being provided thereby promoting their capability and resilience know-how and again such approach would provide supportive environment for community members to explore practices that would promote governance.

5.6 Summary chapter

In this chapter the appropriate implementation plan for local groundwater governance using Ostrom design principles of good governance for domestic water demand and use has been investigated and results have been discussed. The research question on what is the appropriate implementation plan that is required for local groundwater good governance practice has been answered. The use of thematic-content analysis from interview results was used to assess some aspects of local level governance for groundwater demand and use in the study area was adequately applied, but inevitably, local governance issues for groundwater demand and use cannot be fully met without anthropological approaches that require long-term observation of various socio-political-cultural aspects. The Ostrom design principles for governance in the context of groundwater resources at local village level during drought events in Ha-Lambani Village were applied. The discussion has provided some reported limitations of the principles in Ha-Lambani Village regardless of empirical evidence of successful application of such principles in many areas as presented in Chapter 2 of this thesis. These are universal agreed upon principles for governance. In addition, governance provisions at local level for the study area appeared to be insufficient to deal with the prevailing drought events, even though there are some provisions. However, implementation and capacity seem to be lacking in Ha-Lambani Village. These findings reinforce the argument in this chapter, that a plan that considers local context would be ideal to implement local governance practice for sustainable management and utilization of groundwater especially during drought events. Based on such findings, an implementation plan with activities and methods that aim at promoting good governance for groundwater at local level using Ha-Lambani Village as a case study was designed. In addition, a proposal to conduct a detailed field observations and consultative meetings with all stakeholders in Ha-Lambani community in addition to relevant Local, District and provincial/ Catchment Management Agency officers on groundwater governance and management was suggested.

CHAPTER 6: APPLICATION OF CAPABILITY, RESILIENCE AND SUSTAINABLE RURAL LIVELIHOODS APPROACHES

6.1 Introduction

The literature on the theories, concepts and approaches that informed the current study on domestic water demand, use and its governance in rural areas during drought was reviewed. These theories provided assumptions and principles in their original and modified versions over time by various scholars in different contexts and the findings of the present study were discussed alongside such assumptions and principles. Explanations on why and how such theories and approaches were used in the current study are provided.

6.2 Overview on methods used for synthesis of evidence

Evidence from various sources of data was verified using various techniques for reliability and validity of such data and their interpretation. For example, different aspects of rigour for this study were adhered to through trustworthiness or dependability aspects. This was done by asking similar questions to participants at different times to check the consistence of their responses (Brink, 1991; Creswell et al., 2000; Gibbs, 2007). The aim was to check if the different categories of participants (focus group discussion [FGDs], key informant interview [KII], observation and individual interviews) provided similar responses on the same question. Triangulation was also used where different data collection methods (interviews, observation and records review) were engaged as well as using different sources of information (Denzin & Lincoln, 1994; Patton, 2002; Creswell, 2013). Employing multiple data collection methods increases the credibility of the findings by eliminating or reducing errors linked to one particular method. The researcher used observations, Focus Group Discussions (FGDs) and individual interviews to collect data from participants on the same subject. In this way, the researcher was able to cross-check or compare responses from different methods with different categories of study participants. Triangulation was used to adequately address the problem of rival explanations. All these techniques as discussed in Chapter 3 of the present thesis helped discussing the application of the capability, resilience and sustainable rural livelihood approaches from results of the current study in Ha-Lambani Village.

6.3 Applying capability and resilience approaches to domestic water demand and use

Findings on the capability of communities to deal with the effects of drought were discussed using the Capability Approach (CA) as the theoretical framework for the study. Despite the CA being economic framework that assesses poverty and human development using equalities in society as indicator (Clark, 2005), the approach was used to evaluate poverty-related phenomena in societies in line with what Goldin (2013) proposed. For the current study, the following key results were obtained from the Ha-Lambani Village Communities such as "the ownership of water sources and, associated rules on looking after and, using such resources" were partly reported to exist and there were more similar to principle one.

During FGDs, it was clear that operational rules were discussed and agreed upon among users of resources in the village including water. During field observation, it was confirmed that the schools board assigned one person from the same village to look after groundwater resource at the boreholes which was located in the school yard. During Focus Group Discussions (FGDs) and Key Information Interviews (KII), it was reported that they do not like punishments for the fellow community members who break the community rules but they encourage such deviants or defaulters to comply with agreed upon operational rules in the community. The FGDs and KII revealed the existence of measures to manage conflicts such as committees and the Chief sometimes. In addition, it was reported and groundtruthed that the community had boreholes at school drilled (groundwater) by government, and community tap by local municipality. It was reported that these sources were governed and managed by school committee and community committee. In summary, it was found that that community had multiple sources of water for their uses which included boreholes, open wells which are groundwater and community taps and rivers which are surface water source. As discussed in chapter 2 that that central message in the capability CA is about what people are able to do (opportunity) or capable of doing. This was that notion that guided the research questions for present study.

The findings in the present study showed that community had groundwater sources to supply them with water during drought. Groundwater resources are less affected by drought based of the type of the aquifer where such water resides. The open wells in the community draw its water from shallow and unconfined aquifer which is vulnerable to drought effects. However the presence of Boreholes in the community like the one at school and clinic suggest that these water sources draw groundwater from deeper and confined aquifers which are resilience to effect of drought. Details about groundwater occurrence and factors for recharge have been discussed in Chapter 4 of the present thesis and such a description will not be repeated in the current chapter. However, it is important to state that Ha-Lambani Village has multiple sources of water for domestic uses. This discussion helped to answer the research question of the current study in terms of people what are able to do to positively adapt to adverse events of droughts.

The Capability Theory was used alongside the theoretical concept of resilience which refers to people's ability to successfully adapt to life tasks during adverse conditions/events. Finding from Ha-Lambani Village although not conclusively but they have provided critical insights on what people do to adapt to adverse effects of climate change variability such drought. Findings from Ha-Lambani Village on implementing community operational rules on how to govern their groundwater resources and in addition of having multiple sources of water in time of drought are in line with what Pecillo (2016) found on the application the resilience concept found when he stated that states that resilient people have, through time, developed proper coping techniques that allow them to effectively and relatively easily move around and through crisis. The present study explored what people were capable of doing in Ha-Lambani Village to enable them to adapt, and even to thrive, during adverse events of drought and found that multiple sources of water and implantation of community operational rules that aim at inclusive community engagement through meeting and meriting of the groundwater resources were some of the key aspects to ensuring sustainable water supply for their uses during drought. The CA and RC were successfully applied in the current study in proving the meaning in terms of what people do when they are faced with effects of drought.

The current study used the concept resilience as the conceptual model (theme) for the study where the term resilience has been defined by various authors in different context (Perrings, 2006; Gunderson &Light, 2006; & Keessen et al., 2013; Southwick 2014; & Pecillo, 2016) as provided for in Chapter 2 of the current thesis. Although the review from the above scholars offer the same meaning about the definition of the concept of resilience, the definition offered by Pecillo (2016) and Fleming & Ledogar (2010) informed the operation understanding of the concept of resilience for the current study which aligned well with the research question of this study which seeks to answer "What do people do during prevailing hard times such as drought to adapt positively?" The hypothesis of the present study was that unless what people do when they are faced with hardships during droughts is known or investigated, any intervention designed for such people will not be long lasting for them. Alternatively, the present study argued that it is important to investigate people's ability to a successfully adapt to adverse events such drought. When this thesis was tested in Ha- Lambani Village, findings showed local governance in terms of community rules on the use of water from various sources provided a platform for their resilience to effect of drought thereby addressing the research question of what do people do to offset their hardships.

6.4 Applying SLA approach to domestic water demand and use

The sustainable livelihood approach (SLA) has four major aspects, namely, vulnerability context, direct influencing factors, types of assets and livelihood outcome; Example of vulnerability context include: drought, flood, cyclones, diseases, population, economic growth, technology change, rural infrastructure, natural resource seasonality, health seasons laity, employment availability, market demand, ownership of the commons, resource trends, political trends, health trends, conflict, globalization. Examples of direct influencing factors include: religion, taboo, social norms, caste class, gender, age, power, patronage, governance resources access, knowledge, information, decision-making, policy, law, regulations, service delivery, economics and markets. Examples of assets types that define the coastal poor include human, natural, physical, financial and social assets. Example of livelihood outcome include: Wellbeing health, incomes, happiness, knowledge, stable natural resources, choice, security, inclusion (Scoones 1998; Ellis, 1999; Ashley, 2000; Baumann 2000;Carney, 2000).

In chapter 2 the reviews showed that sustainable livelihoods approach (SLA) has been explained and expanded by several (Scoones 1998; Ellis, 1999; Ashley, 2000; Baumann 2000;Carney, 2000).Therefore, many details on the approach were left out in the present study. However, a brief synopsis of the main principles underlying SLA and aspects were presented as SLA framework for the present study and only selected aspects of the four major aspects of SLA were applied to the findings on the present study. Such aspects included vulnerability context (drought), influencing factors (resource access), assets (groundwater as natural assets), strategies (research question) and livelihoods outcome (water security).

The present study found that Ha-Lambani Village as a community had committees on water resources and such committees had operational rules which are part of the intuitional arrangement and operational mechanism which were aligned well with Ostrom design principles of good governance in water resources at local level. These findings agreed with FAO‟s use of the SLA where the aim is to foster local institutions for improving rural livelihoods and ensuring equitable access to resources such as water demand and use in the current study. In addition, the SLA strengthened links of local institutions to appropriate local municipality and district municipality to regional and national institutions. For example, the findings in Ha-Lambani community, led to a suggestion that relevant officers for Thulamela Local Municipality and Vhembe District Municipality and Limpopo Catchment Management Agency would need to be represented in groundwater governance and management committees at all levels to contribute towards decision support system and its implementation at local levels where actions matter. In this study, the Ha-Lambani Village mattered.

The findings and suggestion in the Ha-Lambani Village aligned with the study by Bennette, (2010). The principle behind the sustainable livelihoods approach SLA is to build capacity of local institutions and empowering local populations through their participation in governing and managing their water resources especially during drought events. Findings from the Ha-Lambani Village as a community showed such application when local governance was tested using Ostrom design principles of good governance at local scale. Application of the SLA in Ha-Lambani Village showed that the SLA had potential to enable people to cope with and recover from adverse effects of drought events; maintain and enhance people's capabilities through local governance structures and enforcement of its operational rules as was the case or findings in a study by (Scoones, 1998). One of the reasons as to why the SLA was used was that the framework is not used in isolation but bring together different perspectives for contributing to a people-centred approach and SLA is used as a tool to designing intervention as explained in (Ashley & Hussein, 2000; Manzetti, 2001; Baumann, 2000). In the present study, the SLA was used alongside the capability and resilience approaches in pursuit to answer the research question of the present study which was what people do to adapt or sustain their water demand and use livelihoods with the aim of designing an implementation framework that ensures local governance intervention of groundwater resources during drought events in rural areas. Thus, it can be reported that SLA was applicable in the present study to answer the research question thereby addressing the last objective of the study.

6.5 Summary chapter

There is a considerable argument among water resource manager on how to apply some approaches such as capability, resilience and sustainable rural livelihoods in the utilization and management of water resources especially groundwater at local level in terms of what parameters need to be studied or investigated to provide reliable and valid results for plausible interpretation of such findings. A brief summary of the main principles underlying SLA and aspects were provided. For example, the selected aspects that were studied included drought (vulnerability context), resource access (influencing factor), groundwater as natural assets and water security as a livelihood outcome with focus on water demand and use.

This SLA was used alongside the capability and resilience approaches in pursuit to answer the research question of the present study which was what people do to adapt or sustain their water demand and use livelihoods with the aim of designing an implementation framework that ensures local governance intervention of groundwater resources during drought events in rural areas. The results showed that relevant officers for Thulamela Local Municipality and Vhembe District Municipality and Limpopo Catchment Management Agency would need to be represented in groundwater governance and management committees at all levels to input into decision-making process towards implementation of such decisions at local levels where actions matter. In addition, Ha-Lambani Village as a community had committees on water resources and such committees had operational rules which were part of the intuitional arrangement and operational mechanism which were aligned well with Ostrom design principles of good governance in water resources at local level. Such findings had potential to foster local institutions for improving water security in drought periods thereby ensuring equitable access to resources for their improved water security as livelihoods outcome.

Chapter 7: Conclusion and recommendations

7.1 Introduction

The main aim for the present study was to assess rural domestic water demand and use that would inform a basis for designing an implementation plan for local groundwater good governance as an intervention during drought in rural unmetered areas. Ha-Lambani Village in Limpopo Province of South Africa was used as case study. This study was informed by capability, resilience and sustainable livelihood approaches as theoretical and analytical frameworks to facilitate interpretation of the results on coping mechanisms practiced by rural households during extreme weather events such as drought. Based on such study purpose, five study objectives were formulated to i) Explain the influence of physiographic factors on groundwater availability; ii) assess rural domestic water demand and use using indirect methods; iii) determine factors for rural domestic water demand and use using regression analysis; iv) explore appropriate implementation plan for local groundwater governance using Ostrom design principles of good governance for domestic water demand and use; and v) assess the application of capability, resilience and sustainable livelihoods approaches as a feasible framework for better understanding coping strategies during drought events. Results from study objectives 1, 2 and 3 were presented and discussed in chapter four and chapters 5 and 6 presented findings from objectives 4 and 5 respectively.

7.2 Conclusion and recommendation on each study objective

Since the sustainable livelihoods approach (SLA) as an analytical framework as design is used in alongside other approaches such as capability approach (CA) and resilience approach/concept (RA) to bring together different perspectives for contributing to a people-centred approach, such methodology was followed to design an implementation plan as presented in Chapter 5 of the present thesis. In addition the SLA is meant to promote managing water resources in a coordinated manner among stakeholders and the present study has provided the required knowledge about the factors that explain groundwater availability, demand and use in addition to showcasing the methodology for computing groundwater demand and use in unmetered rural areas as a basis for more robust methods. Such computation provided information on water demand and use realizing that the balance between water abstraction for use and water governance require such information for implementing local governance and management actions on local groundwater resources to enable people to sustainably e access such waters especially during drought periods. An improvement in the knowledge of factors that explain the availability, demand, use and governance of groundwater also informed the basis for identifying opportunities for using water to improve livelihoods outcomes of people in particular local areas. It can be concluded that the study has provided scientific and societal value in its conception and implementation.

7.2.1 Assessing groundwater availability and domestic water demand and use

The three study objectives on explaining the influence of physiographic factors on groundwater availability; assessing rural domestic water demand and use using indirect methods; and determining factors for rural domestic water demand and use using regression analysis were combined and presented in Chapter 4 of the present thesis. Using visual tools such as maps, photos and physiographic factors, this research identified and described physical factors that explain the groundwater availability in the study area qualitatively. For example, following physiographic factors were identified to explain how each one of them influence groundwater availability in Ha-Lambani Village: a) Climate in terms of precipitation, b) soil and geology, c) topography, d) hydrology, e) land cover and land use including settlement pattern. From the recharge mechanism and hydrology perspectives and using qualitative assessment of such factors, Ha-Lambani Village showed limited groundwater availability. In this case, qualitative assessment provided insight on groundwater availability thereby shedding light on what to measure when quantitative analysis of demand and use of groundwater is being planned in future. These findings study confirmed the water scarcity situation in Ha-Lambani Village and since the study area was in semi-arid environment and in South Africa which is described as a physically water scarce country, such findings were not surprising. Therefore, lobbying for the design of an appropriate implementation plan for good governance and management of such water resources was viewed as one of the most viable and rational action plan for sustainable utilization of such waters especially in the context of drought events.

The use of the proposed approach on calculation water demand and use in unmetered rural areas, though time-consuming provided a basis for providing systematic data that can inform a quantitative understanding among key water stakeholders for implementing action plan at sub-catchment level. The detailed statistical computation used in this study and discussion on its strengths and weaknesses provided enlightenment on interpreting results from such method thereby proving opportunities for further researchers to refine the methodology. The systematic computational procedure provided is a major step towards a more informed procedural assessment approach on data generation and its implication for managing water in a coordinated manner in the communities especially in rural unmetered communities. As a showcase study, findings from the Ha-Lambani Village demonstrated procedures that were followed to generate statistics on demand and use of rural domestic water at household level. Such results highlighted evidence-based guide on how to generated statistics that are usually required for guiding the design of implementation plan that have potential to promote local groundwater good governance practice. The assessment on determinants of demand and use of such waters contributed to a comprehensive assessment of factors that explain the key drivers for observed abstraction and consumption of groundwater in the study area. The assumption is that generation of statistical estimates contributes towards decision making in term of the appropriateness of the implementation plan for water utilization and management practices. To make confident statements on local good governance of groundwater, statistics need to be provided on the volumes of water abstracted and consumed that are observed being in communities. Such quantitative assessment forms the basis for evidence on the needed confidence for promoting local governance and management of water resources especially during droughts events. Therefore, the first four objectives of the study were fulfilled on explaining the influence of physiographic factors on groundwater availability; assessing rural domestic water demand and use using indirect methods; and determining factors for rural domestic water demand and use using regression analysis as provided for in Chapter 4 of the present thesis.

7.2.2 Designing implementation plan for local groundwater governance for domestic water demand and use

The overall assessment on the fourth objective of the present study which focused on exploring appropriate implementation plan for local groundwater governance showed that application of the Ostrom design principles of good governance for domestic water demand was appropriate approach. Details on the findings on objective four were presented and discussed in chapter 5. These findings reinforced the argument or the thesis of the objective four of present study which stated that "a plan that considers local context would be ideal to implement local governance practice for sustainable management and utilization of groundwater especially during drought events". Based on such findings, an implementation plan with activities and methods that aim at promoting good governance for groundwater at local level using Ha-Lambani Village as a case study was designed. In addition, a proposal to conduct a detailed field observations and consultative meetings with all stakeholders (organisations, clubs, committees, individuals) in Ha-Lambani community in addition to relevant officers for Thulamela Local Municipality and Vhembe District Municipality and Limpopo Catchment Management Agency on groundwater governance and management was suggested. Therefore, the fourth objective of this study on exploring appropriate implementation plan for local groundwater governance using the Ostrom design principles of good governance for domestic water demand was been fulfilled.

7.2.3 Assessing the application of the capability, resilience and sustainable rural livelihoods approaches for rural domestic water demand and use

The application of capability, resilience and sustainable livelihoods approaches as a feasible framework for better understanding coping strategies during drought events was proved successful in the present study when it was applied in the Ha-Lambani Village. The application of the above approaches was the fifth and last objective of the current study and detailed results on the above approaches were presented and discussed in chapter 6. Despite the qualitative methodology that was followed on the last objective on application of the approaches, the selected aspects of the SLA provided critical insights on livelihoods outcome of the people in their vulnerability context (drought). In other words, key issues come out clearly on what people do or are capable of doing when they are faced with challenges during the drought events which provided a starting pointing interrogating the possible most appropriate and acceptable intervention that would sustain peoples access to water resources when they faced with negative effects of climatic variability such as drought events. Such observation or insight provided a compelling evidence to lobby for designing appropriate implementation plan with well-defined monitoring, evaluation and reports tools for sustainable utilization and management of groundwater resources especially in the context of vulnerability. This study recommends the continuous application of the SLA in combination of the capability and resilience concepts when assessing groundwater governance and management especially at local scale where actions matter.

There is a considerable argument among water resource manager on how to apply some approaches such as capability, resilience and sustainable rural livelihoods in the utilization and management of water resources especially groundwater at local level in terms of what parameters need to be studied or investigated to provide reliable and valid results for plausible interpretation of such findings. The sustainable livelihoods approach (SLA) was applied alongside the capability and resilience approaches in pursuit to answer the research question of the present study which was what people do to adapt or sustain their water demand and use livelihoods with the aim of designing an implementation framework that ensures local governance intervention of groundwater resources during drought events in rural areas. The results showed that relevant officers for Thulamela Local Municipality and Vhembe District Municipality and Limpopo Catchment Management Agency would need to be represented in groundwater governance and management committees at all levels to input into decision-making process towards implementation of such decisions at local levels where actions matter. Secondly, the Ha-Lambani Village as a community had committees with operational rules on water utilization and management which were part of the intuitional arrangement and operational mechanism which aligned well with Ostrom design principles of good governance in water resources at local level. Such findings had potential to foster local institutions for improving water security in drought periods thereby ensuring equitable access to resources for their improved water security as livelihoods outcome.

This study recommends such local participation and initiatives as proxy for the full and successful groundwater governance at local scale, the community. Therefore, the fifth objective of this study on assessing the application of the application of capability, resilience and sustainable livelihoods approaches as a feasible framework for better understanding coping strategies during drought events was fulfilled.

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