Household water insecurity in a coupled human and natural system: Empirical evidence from rural and peri-urban communities of Limpopo, South Africa

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Thesis to obtain the Master of Science Degree in

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Resumo

A segurança da água é uma questão global central no mundo de hoje através de geografias de escalas internacionais a locais. A nível doméstico, a insegurança hídrica tem sérias implicações para o bem-estar, a subsistência e a saúde em todo o mundo. Apesar da sua importância, permanecem múltiplas definições de insegurança hídrica e há falta de uma ferramenta analítica adequada para medir a insegurança hídrica ao nível doméstico. Informado por uma epistemologia pragmática no âmbito da presente pesquisa, utilizei uma abordagem quantitativa e qualitativa mista para desenvolver uma escala de insegurança hídrica de nível doméstico (HWI) inovadora, confiável e validada para medir, caracterizar e analisar a determinantes multidimensionais da insegurança hídrica. A escala desenvolvida é então colocada em um contexto mais amplo de sistema humano e natural acoplado (CHANS) para vincular e analisar a inter-relação entre vários estressores sócio-ecológicos, sócio-hidrológicos e institucionais. Em um contexto sul-africano, embora as conseqüências da insegurança hídrica estejam bem documentadas, a variação nos determinantes sociais e físicos da insegurança hídrica em nível doméstico em paisagens rurais e peri-urbanas é uma preocupação crescente e foco de pesquisa que Esta pesquisa atual ajuda a avançar.

A África do Sul é um dos 40 países mais secos do mundo, e o desenvolvimento econômico da nação está intimamente ligado à sua segurança hídrica. A análise estatística dos dados climáticos anteriores mostrou a presença de um regime climático altamente variável com um número decrescente de dias chuvosos, chuvas sazonais totais e chances crescentes de eventos extremos esporádicos. Uma análise de quadro institucional integrada de cima para baixo e de baixo para cima destacou as percepções e questões societais existentes para o acesso à água dentro do sistema de estudo entre os diversos atores. Para o estudo das respostas societais, realizou-se um levantamento transversal de domicílios (n = 131), e utilizou-se a análise estatística dos dados da pesquisa para desenvolver a escala HWI. Emergiram três domínios de insegurança hídrica domiciliar: (1) percepção do acesso à água deficiente, (2) percepção da qualidade da água insegura e (3) percepção da oportunidade perdida e das redes sociais. A escala desenvolvida assim ajudou a compreender a construção latente do sofrimento emocional causado pela insegurança hídrica. A pesquisa também destacou uma correlação estatisticamente significante entre a água do agregado familiar e a insegurança alimentar. Apesar dos avanços passados recentes feitos pelos governos locais em melhorar vastamente a entrega do serviço de água, os agregados familiares são furados em um waterscape do acesso de água pobre e da qualidade que conduzem à qualidade de vida pobre nestas comunidades marginalizadas. Além disso, o escopo de pesquisa atual, um inquérito de vontade de pagar (WTP) (n = 66) foi conduzido em uma comunidade de águas subterrâneas e uma superfície dependente de água. A análise estatística da pesquisa da WTP inferiu que as famílias estão dispostas a pagar por serviços hídricos melhorados.

Assim, os resultados indicam que o aumento do stress hídrico, do crescimento populacional, das relações de oferta-procura, da variabilidade climática, da redução da quantidade de água, da má qualidade, das barreiras institucionais e sócio-ecológicas pode afectar o crescimento económico e desenvolvimento sustentável. Melhor manejo de águas subterrâneas, medidas de proteção de fontes, tratamento de água local e sistemas de rereticulação de água adequadamente operados e gerenciados podem aprimorar o suprimento de água doméstico confiável e adequado. Além disso, o aumento da conscientização entre os vários atores e a implementação de um mecanismo de recuperação de custos sustentáveis pode ser útil para melhorar as infraestruturas de água e a relação sociedade-governo local.

Palavras-chave: política ambiental, adaptação, Limpopo, análise de componentes principais, sócio-ecohidrologia, insegurança hídrica doméstica

Abstract

Water security is a central global issue in today's world across geographies from international to local scales. At a household level, water insecurity has severe implications for wellbeing, livelihood and health across the globe. Despite its importance, there remain multiple definitions of water insecurity and lack of an appropriate analytical tool to measure household-level water insecurity. Informed by a pragmatic epistemology within the present research scope, I used a mixed quantitative and qualitative approach to develop a novel, reliable and validated household-level water insecurity (HWI) scale to measure, characterise and analyse the multi-dimensional determinants of water insecurity. The developed scale is then put in a broader context of coupled human and natural system (CHANS) framework to link and analyse the interrelation amongst various socio-ecological, socio-hydrological and institutional stressors. In a South African context, although the consequences of water insecurity are well documented, the variation in social and physical determinants of household-level water insecurity in rural and peri-urban landscapes is a growing concern and research focus which this current research help advance.

South Africa is one of the forty driest countries in the world, and the nation's economic development is closely linked to its water security. Statistical analysis of past climate data showed the presence of a highly variable climatic regime with a decreasing number of rainy days, total seasonal rainfall and increasing chances of sporadic extreme events. An integrated top-down and bottom-up institutional framework analysis highlighted the existing societal perceptions and issues to water access within the study system amongst the various actors. To study the societal responses, a cross-sectional household survey was conducted (n = 131), and statistical analysis of survey data was used to develop the HWI scale. Three domains of household water insecurity emerged: (1) perception of poor water access, (2) perception of unsafe water quality and (3) perception of lost opportunity and social networks. The developed scale thus helped understand the latent construct of emotional distress as caused by water insecurity. The research also highlighted a statistically significant correlation between household water and food insecurity. Despite recent past advancements made by the local governments in vastly improving water service delivery, households are stuck in a waterscape of poor water access and quality leading to poor quality of life in these marginalized communities. Further, under present research scope, a willingness to pay (WTP) survey (n = 66) was conducted across one groundwater and one surface water dependent community. The statistical analysis of the WTP survey inferred that households are willing to pay for improved water services.

The results thus indicate that increasing water stress, population growth, supply-demand ratios, climate variability, reduced water quantity, poor quality, institutional and socio-eco-hydrological barriers can thus affect the economic growth and sustainable development. Improved groundwater management, source protection measures, local water treatment and appropriately operated and managed water reticulation systems can enhance reliable and adequate domestic water supply. Additionally, increased awareness amongst the various actors and implementation of a sustainable cost recovery mechanism can be useful in improving the water infrastructures and society-local government relationship.

Keywords: environmental policy, adaptation, Limpopo, principal component analysis, socio-ecohydrology, household water insecurity

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Abbreviations

RSA	Republic of South Africa
SDG	Sustainable Development Goals
MDG	Millennium Development Goals
IWRM	Integrated water resources management
CHANS	Coupled human natural system
ADB	Asian Development Bank
DBSA	Development Bank of South Africa
GWP	Global Water Partnership
HWI	Household water insecurity
WSA	Water Service Act
NWA	National Water Act
DWS	Department of Water and Sanitation[1]
CMA	Catchment Management Agency
WSP	Water Service Provider
WSA	Water Service Authority
CoGTA	Department of Cooperative Governance and Traditional Affairs
OTP	Office of the Premier
IGR	Department of Intergovernmental Relations
RDP	Reconstruction and Development Program
FBW	Free Basic Water
EFA	Exploratory factor analysis
PCA	Principal component analysis
CVM	Contingent valuation model
CM	Choice model
WTP	Willingness to pay
CLM	Conditional logit model

[1] Formerly known as DWAF (Department of Water Affairs and Forestry)

CHAPTER 1

Introduction

1.1 Background

Water is a vital resource for life, and its security is a growing concern, and one of the biggest challenges of the 21st century. Ensuring the security of mobile and shared resource such as water is complex across time and space. Various natural, social, anthropogenic (i.e. climate change, increasing population and human-environment interactions) and institutional drivers pose complications in ensuring safe and adequate water resources across the world. Such interdependencies between humans and the natural ecosystem system we live in, lead to trade-offs and cross-scale feedbacks across geographies (Srinivasan *et al.*, 2017). In addition to these coupled effects, there is an increasing competition of water demand, supply and usage between the various sectors of economies and societies under increasing and varying biophysical changes. Water security gained global prevalence with the United Nations recognizing clean drinking water and sanitation as essential human rights through its Resolution 64/292, on July 28, 2010 (United Nations General Assembly, 2010). During the millennium development goal campaign (MDG, 1990-2015) of the United Nations, 2.6 billion people across the globe gained access to improved sources of drinking water (Stevenson *et al.*, 2012). At present the sixth sustainable development goal (SDG 6) - 'to ensure the availability and sustainable management of water and sanitation for all'- highlights the importance of water resources under changing climate and societal advancement. Globally, people still lack access to safely managed water supplies and the challenge to sustainably meet the future water demand is increasingly daunting. According to the United Nation Synthesis Report on Water and Sanitation 2018, 3 out of 10 people lack access to safe drinking water which estimates to 844 million people globally; still lacking a basic level of water service (United Nations, 2018).

Over the past decades and specially since the implementation of the SDGs, various approaches to conceptualize and operationalize water security has grown through advancements by several governmental and non-governmental organizations, scholars and policymakers (Cook and Bakker, 2012; Garfin, *et al.*, 2013; UN-Water, 2013; W. E. Jepson *et al.*, 2017; Gerlak *et al.*, 2018). Water security and or insecurity has been applied to several subject areas and defined under numerous thematic attributes, addressing multiple domains of water resources and management. International agencies determine water security as adequate, reliable and affordable water and sanitation at all times (GWP, 2000; UN-Water, 2013). Further water security has also been defined with emphasis on vulnerability and risk (Garrick and Hall, 2014), environmental sustainability and adaptation (Scott et al., 2013), human rights (Crespo and Walnycki, 2012),quantity and quality (Cook, 2016; James *et al.*, 2017; Gunda et al., 2019), geopolitics and international relations and human development (Asthana and Shukla, 2014). The concept of water security has been identified as an evolving and goal-oriented emerging paradigm (Horney et al., 2017; Gerlak et al., 2018; Jensen & Wu, 2018; Cook & Bakker, 2012). Therefore at present, given the varied complexities of defining water security, there is a lack of global consensus towards addressing 'what is to be secured' and its consequent translation into governance and policy. Since its inception, water security and or insecurity measurements have been conducted with several indices used for quantitative and qualitative approaches such as water scarcity, water poverty, water vulnerability and water security (Molle and Mollinga, 2003; Falkenmark *et al.*, 2007; Gunda, Benneyworth and Burchfield, 2015; Plummer, Loe and Armitage, 2015). Such indices use a singular or multiple domains of water security/ insecurity for a place-based measurement as a snapshot in time; at a global, national, transboundary river basin, community or an individual level. Within the framework of human need and development, water security has been traditionally framed as a subset of food security whereby it is susceptible to water scarcity, vulnerability and risks to a hydrological cycle (Cook and Bakker, 2012). Additionally, macro-level scales though applicable globally or nationally fails to capture the varied lived emotions and experiences of individuals and households at ground level (Jepson, 2014). Recent advancements in household water security and insecurity studies have shown the development of several perception-based scales and identifying the relationship of such scales to varied physical dimensions of water issues such as access, quantity and quality to determine pathways of water (in)security. Irrespective of these advancement multiple definitions of water (in)security and the lack of a universally quantifiable analytical tool is a significant hindrance to categorize household water (in)security (W. E. Jepson *et al.*, 2017). Besides, given the multidimensional nature of water resources, scholars and researchers also have stressed on measuring such scales in relation to social, cultural, economic and political processes using interdisciplinary relational frameworks such as hydrosocial cycle (Linton and Budds, 2014), combined social-ecological systems (Liu *et al.*, 2007), sociohydrology (Konar and Sivapalan, 2017) and human capabilities approach (W. Jepson *et al.*, 2017). Such approaches would help to determine accurately, understand and develop efforts to reduce household water (in)security.

The Republic of South Africa (RSA, henceforth also referred to as South Africa) has been recognized as one of the forty driest countries globally with an average rainfall of approximately 500 mm (Meissner *et al.*, 2018; Steyn *et al.*, 2018). The South African climate is characterized by highly variable rainfall and uneven spatial and temporal distribution of water resources. Under such semi-arid climatic condition, uneven rainfall distribution and high potential evapotranspiration rates lead to extremely low rainfall to runoff conversions leading to highly variable ephemeral stream flows and depleting groundwater reserves (Conway *et al.*, 2009; Fallon *et al.*, 2018). Such variability in combination to sporadic and repeated prolonged droughts which are followed by intense rainfall events due to anomalous El Niño-Southern Oscillation (ENSO) events, makes water a finite and scarce resource in the Southern African context. Limited groundwater recharge hence may severely affect communities dependent on groundwater sources for the domestic and agricultural needs and thereby restrict their water security (Taylor *et al.*, 2012). South Africa’s economic growth is largely dependent on its water resources and therefore its security. The Development Bank of South Africa (DBSA) in 2009, recognised the country could not yet be considered as “water secure” nation and inferred that ineffective management of resources would lead to increased economic and social disparity (Muller *et al.*, 2009). The DBSA also stated that water insecurity in future might arise due to natural disasters such as droughts and floods in combination with poverty, inequality, limited water resources and lack of institutional management. Hence, there has been an increased research focus in South Africa related to the understanding of water system dynamics and addressing its water security. With a population ration of sixty (60%) to forty (40%) living across urban and rural areas, South Africa has access to 77% surface water, 9%groundwater and 14% recycled water. However, communities' dependence on these water sources is unevenly distributed due to lack of water infrastructure with 74% of the rural population entirely dependent on groundwater (i.e. local wells and pumps) (UNESCO WWAP, 2006).

Before gaining independence in 1994, South African water laws were governed by riparian access principle which tied land and water access and rights together, catering primarily to the wealthy and marginalizing the others, leading to the creation of the former “homelands” (Enqvist and Ziervogel, 2019). Post-independence, there was a dynamic shift in water regulation and policy; from water being perceived solely as an economic good to a combined economic and social entity through the implications of a right based National Water Act. The Act defined the state as a custodian of the national water resources, and water was identified as a fundamental right to meet environmental sustainability and basic human needs (RSA, 1998a). With the formulation of the Act, increased emphasis was given to water services to improve the standard of living for one and all. Water allocation was readdressed by the Department of Water Affairs (DWA) who vested newly formed municipalities with the prime responsibility of water allocation to improve water access for domestic uses for all citizens (van Koppen *et al*., 2014). Currently, under the ‘Free Basic Water Access’ (FBW) policy of the South African Constitution, all citizens are entitled to twenty-five litres per capita per day of potable water for consumption, food and sanitation (Goldin and Kgomotso, 2005). The responsibility for ensuring and regulating such free basic access falls under the supervision of respective municipalities with the local governments ensuring the financing, designing, operation and monitoring of such provisions.

Despite the increasing stress on the nation’s water resources, there remains a lack of shared understanding of water security amongst the various stakeholders. This trait is particularly strong in a rural and peri-urban context amongst the various water users, service providers and traditional government structures that are still pertinent within the country. Whereby over the last two decades, South Africa may have moved towards a decentralized framework but end users, remains in a waterscape best defined as a ‘prisoners dilemma’ dominated by lack of adequate water infrastructure, regulation and increasing socio-economic and environmental pressure. The interactions between citizens, municipalities and local governments form the benchmark of legislative arrangements and in turn, manifests an individual’s perception to water security and or insecurity. The local municipalities in South Africa work as independent units with varying degrees of power, resource distribution and organizational structures (Meissner *et al.*, 2018). These local municipalities, in turn, have uneven administrative capabilities and over time has been struggling to monitor water usage adequately and therefore has failed to make cost recovery of water allocation. Such situations have further led to unequal or complete lack of water provision and mismanaged water infrastructures in the rural and peri-urban regions of the country. Therefore, the dilemma of ensuring water security in such context becomes two-fold. Firstly citizens may feel entitled to their free basic water consumption on the one hand and the municipalities either fail to recur to such needs and or secondly the municipalities fail to operate and maintain the water supply schemes (Calfucoy and Davison, 2009). Such an uneasy relationship has led to a disbalance between gaining social equity and the rapid need for economic efficiency. Hence there is an urgent need for capacity development to make citizens aware of their sustainable use of free basic water and the local governments to improve their physical and economic access to such services (Earle *et al.*, 2005). Combination of all these factors makes water security in the rural and peri-urban communities of South Africa governed under complex social, political, economic, physical and eco-hydrological systems at work. Dynamics of securing water resources in such complex waterscapes thus become a product of coupled human and natural system (CHANS) interactions and are needed to be understood as same.

1.2 Problem statement

Water is a critical resource for human development and survival and hence is at the centre stage for the achievement of all Sustainable Development Goals (SDGs) and in particular to SDG 6. Globally, many rural households still lack access to safe drinking water and are dependent on varied unsafe sources such as rivers, dams, unprotected dug wells or springs and polluted wastewater for domestic purposes making themselves the most vulnerable. Such characteristics further create a significant disparity amongst societal dimensions; i.e. rural and urban, rich and poor. In South Africa, there is an increasing growth of rural and peri-urban population. The rapid growth of informal settlements poses a further challenge to local governments in the provision of water supply, social and economic development. 74% of the rural and peri-urban population is entirely dependent on groundwater, which constitutes only 9% of the nation's water resource. 19% of the population still lack access to safe water and 33% to basic sanitation (UNESCO WWAP, 2006). Regardless of increased provision of safe water through piped systems, governments may lack the capacity to build infrastructure and meet demands of growing urban and rural population or face challenges of unregulated and informal water arrangements (Baker, 2010; Ahlers *et al.*, 2014; Beresford and Carvajal, 2016). Such is also the case with communities within the study area of Hout catchment of Limpopo Basin in RSA. In these rural and peri-urban communities, the access to safe water may have vastly increased over the last two decades, but there remains conundrum in terms of infrastructure maintenance, water supply, demand, access and various other social, political and eco-hydrological determinants.

Irrespective of the importance of water to human dimensions there remains several diverse definitions and a lack of a useful quantitative and qualitative tool to measure water insecurity at household and individual levels across geographies (Wutich *et al.*, 2017). Recent advancements by scholars and researchers have portrayed that most macro-level scales are ineffective proxies to water (in)security at the community and household level. Use of national administrative and census data fail to capture the minute lived experiences which are highly variable across households and individuals within a community (Wutich, 2009; Jepson, 2014; W. E. Jepson *et al.*, 2017; Wutich *et al.*, 2017; Boateng *et al.*, 2018). In the South African context, such perceived emotions play a crucial role in bridging the gap between citizens and local municipalities. Recent studies in RSA were observed to be focusing on water security as perceived by communities through casual mechanism-based approaches (Meissner *et al.*, 2018; Steyn *et al.*, 2018). Another research linking rural water and food security to smallholder irrigation quantitatively deduced a local water security scale and identified dimensions that affect household water security in terms of an agricultural scheme (Mudhara and Wale, 2014). All these studies have highlighted the importance of water security and insecurity perceptions from a bottom-up approach and calls for further research in terms of employing additional objective measurements such as water source reliability and volume sufficiency. Therefore, identification and quantification of key dimensions of perceived water insecurity at a household level beyond the narrow scope of supply and demand is a developing scope of work in the rural and peri-urban landscapes of RSA. The following research conducted addresses this research gap by adding on to the ongoing global research related to the development of household water (in)security metric based on the household's perceived experiences. The novelty of the work derives from the development and application of a bottom-up household water insecurity scale which is unique to the geographical context of the rural and peri-urban communities of the Hout catchment in the Limpopo basin of South Africa. Further, the research advances the developed scale to understand the various socio-economic, eco-hydrological and institutional relations at play in producing household water insecurity and recurrent feedbacks amongst such dimensions.

1.3 Research objective

The overarching objective of this research is to identify the key determinants of household water insecurity under the relational framework of a coupled human and natural system (CHANS). The study system (Hout catchment) comprises of rural and peri-urban communities which are predominantly groundwater-dependent and severely affected by a semi-arid climatic regime. Besides such eco-hydrological aspects, water access in the study system is determined through several institutional, socio-hydrological and biophysical factors. This research aims to analyse such complex waterscape through an integrated qualitative and quantitative approach. It aims to understand the past climatic trends and institutional frameworks in place related to water resources within the study system. The research further aims to analyse the perceived state of water (in)security through households lived experiences by developing a bottom-up, reliable and validated household-level water insecurity scale. To provide a more holistic understanding of the system dynamics, the research also aims to understand the household's willingness to pay for water services. Thereby the research finally aims to understand, analyse and characterize the pathways, and short-term and long-term feedbacks of various dimensions to household water insecurity in a coupled system.

The scope of present research complements the International Water Management Institute (IWMI) project on 'Enhanced Sustainable Groundwater Use in South Africa' (ESGUSA), a cooperation between the governments of Denmark and Republic of South Africa (RSA). ESGUSA aims to understand and improve the typical hydrogeological settings in semi-arid climate and farming communities of RSA by identification of resource tool indicators and increasing stakeholder involvement in promoting sustainable groundwater management options.

1.4 Research questions

Question 1: What are the institutional mechanisms for water access and provision in the study system?

- Sub Question 1: What is the role of local government in water service provisioning within the study system?
- Sub Question 2: How is the relationship between the end-users and local government in terms of water access and use?

Question 2: Is climate change going to affect existing water access and infrastructures in the near future?

- Sub Question 1: What are the perceptions of stakeholders regarding changes in weather patterns?
- Sub Question 2: What are the perceptions of stakeholders regarding the causes and effects of such climatic changes and variability?

Question 3: What are the key determinants that affect household water insecurity?

- Sub Question 1: Does household water insecurity have any impact on households' food insecurity?

Question 4: Are the households within the study system willing to pay for water services?

1.5 Thesis layout

The following Master's Thesis has been divided into 6 chapters. Chapter 1 provides an introduction to the research by highlighting the background of the research, the research problem and objectives. Chapter 2 provides a detailed literature review on water (in)security from a global to a South African perspective and highlights the advances made in household-level water insecurity. It also highlights previous researches related to institutional frameworks and eco-hydrological changes in relation to water (in)security in South Africa. Chapter 3 provides a broad overview of the study area. Chapter 4 highlights the research paradigm and integrated qualitative and quantitative methods used for analysing the research questions put forward. Chapter 5 provides the various analysis, results and discussions. Each research question has been analysed separately. Following every analysis and discussion, a short-synthesized summary has been provided to maintain a conceptual flow. Chapter 6 highlights the conclusions of the research by summarising the separate dimensions which were analysed. It puts together all the findings and addresses the broad research questions put forth by characterizing the feedbacks and pathways to household-level water insecurity in a CHANS for rural and peri-urban landscapes. The chapter further states the limitations of the research outlines recommendations and future study scopes to conclude the conducted research.

CHAPTER 2

Literature Review

2.1 Water security: A global perspective

Freshwater has been recognized as a fundamental tool towards achieving sustainable development of the planet. While water in itself is a primary global sector but it is also intertwined with several other economies, the ecosystem and is a life-supporting function in itself. Therefore given its prime importance, it has led to wide-scale debates about safety, security, management and sustainability of global water resources (Keskinen and Kummu, 2017). Over the last few years, the decentralized and integrative approach of Integrated Water Resources Management (IWRM) has been one of the most widely adopted, debated and practised water management tools globally. While IWRM allows for stakeholder engagement and inclusivity of social, ecological and infrastructural systems; its focus solely towards the water sector was highly criticized and debated (Varady *et al.*, 2016). This led to the formation of the nexus approach which aimed to combine water, food and energy sectors further to broaden the IWRM approach (Agarwal *et al.*, 2000; Biswas *et al.*, 2004; Giordano and Shah, 2014; Al-saidi and Elagib, 2017). Amongst such debates, the expression of water security, also came to the forefront to quantify the responsiveness, effectiveness and efficiency of IWRM. The concept of water security, in its crux hence brings together the water-related vulnerabilities and societies' adaptive capacities together to form a goal-oriented approach of 'secured' water status (Cook and Bakker, 2012; Garfin, *et al.*, 2013; Beek and Arriens, 2014; Varady *et al.*, 2016; Keskinen and Kummu, 2017). Despite the growing recognition and use of the water security concept, the term 'security' may have multiple meanings; which has led to the widespread articulation of varying definitions and frameworks. Gerlak *et al.* (2018), through their comprehensive literature review of place-based water security, identified that such definitions have been developing with time and adding several dimensions onto the spectrum of water security. Their research also pointed out that, as the notion of water security becomes central to the theme of water policy and management, the debates over it, expands and diversifies.

The concept of water security had its roots in the 1990s and was used primarily across military and food security and rarely towards environmental security. Although over the last two decades, the impression of water security has evolved significantly (Cook and Bakker, 2012). An integrative definition for water security was provided by the Global Water Partnership (GWP) who was responsible for defining and promoting IWRM as well. GWP defined water security from a broad scale of global to household level under the framework of sustainability, ecosystem and hazards; ensuring protection and enhancement of water resources and the environment, to allow safe and affordable water for every human (GWP, 2000). Following this, various scholars, non-scholars and policymakers added further dimensions to broaden the view of water security. Water security was broadened by attributes such as quantity, quality, livelihood and risks (Grey and Sadoff, 2007); quantity, quality, ecosystem and sustainability on a watershed scale (Norman *et al.*, 2010); the role of water security in policy (OECD, 2011); peace and national security (Baker, 2012); resilient societies and uncertain global changes (C.A. Scott *et al.*, 2013), human well-being, socio-economic development and political stability (UN-Water, 2013) and economic, urban, environmental, resilient and domestic domains (ADB, 2013). Besides such widespread definitions and frameworks, water security has been used variedly across several disciplines such as agriculture, engineering, environmental sciences, fisheries, geology, public health, anthropology, economics, policy and water resources (Cook and Bakker, 2012). Since its rapid emergence over the last two decades, water security studies and researches have applied the concept across geographies and varied scales of global to regional and local scale (i.e. city or community). These studies have been conducted either focusing solely on humans or a human and environment confluence. Security has been focused upon multiple sources of water (i.e. surface water, rainwater, groundwater, stormwater and desalinated water). Gerlak *et al.*, (2018) highlighted that in a Sub Saharan context the significance of water security studies has been more focused on regional and local scales primarily addressing dimensions of quantity, quality and water for agriculture. Their research also highlights that majorly in a Sub Saharan context, water security studies are linked with groundwater and rainwater. This trait portrays that arid climatic regions are more prone to relying on diversified water sources apart from surface water. Such a trait may come as a response to prolonged droughts and abrupt climatic variability.

Water security hence integrates the core elements of IWRM across scales and is inclusive of its significant dimensions, i.e. water quantity, quality, hazards and access. Significant concerns that lead to characterizing water insecurity has been determined as: populations threatened due to polluted and or depleting water resources, the threat to economic livelihoods and growth, the threat to ecosystem services, and eco-hydrological threats arising due to climatic variability (Cook and Bakker, 2012; Varady *et al.*, 2016). Various tools have been used over time to measure water security. Qualitative predictors, quantitative indicators and or combination of both have been used to identify and measure various metrics of water security and or insecurity. Irrespective of the geographical location the most widely quantified and described indicators of water security has been quantity, quality and accessibility. Since the inception of the water security framework, several metrics and indices have been developed to measure indicators of human water interactions. Gerlak *et al.*, (2018) indicates a linear growth of quantitative over qualitative indices and stresses on the identification of theoretical and conceptual need for multiple domains of water security across different scales (i.e. household, environment, nation transboundary, etc.). The scale at which a water security study is to be conducted predominantly varies across disciplines and research focus. Developmental studies focus on national scales, hydrologist on watershed and transboundary scales, and social scientists work at regional and local scales (Cook and Bakker, 2012). Numerous water security metrics related to water stress (Falkenmark *et al.*, 2007), water shortage (Falkenmark and Molden, 2008), water poverty (Molle and Mollinga, 2003), water vulnerability (Plummer *et al.*, 2015), water scarcity (Gunda *et al.*, 2015), climate vulnerability (Sullivan *et al.*, 2005) and water insecurity index (Aggarwal *et al.*, 2014) has been formulated over time and has been used as proxies to measure water security and or insecurity across space and time.

It has been established that dynamic interactions between socio-political, eco-hydrological and biophysical systems may affect the water security of a state (Zeitoun, 2011; Scott *et al.*, 2013). Cross-scale feedbacks of water security have been shown as examples of Arizona, USA, where groundwater pumping has reduced agricultural and urban water supply which has led to loss and encroachment of forest as an ecological feedback and subsequent use of effluent from wastewater treatment plant for water allocation as a social feedback (Varis *et al.*, 2017). Another example is from Chennai, India, where a study of urban resilience showed that when urban households invested in wells it increased their water security in the short term, but the whole city become more vulnerable over a more extended period (Srinivasan *et al.*, 2013). Nonetheless, there remain questions over the use of qualitative versus quantitative indicators and an integrated versus reductionist approach to water security. In a comprehensive review to water, security approaches. Cook and Bakker (2012) argue for an integrative and broad conceptualization to advance water security and related governance. They suggest that an integrative approach remains true to IWRM concept of integrating quantity, quality, ecosystem and human health concern.

Additionally, such an approach is comprehensive and is goal-oriented at a basin-scale and allows implications of robust monitoring. However, such a broad approach faces the challenge at an operational level and hence to tackle such operational challenges a narrower framing is "both useful and necessary" (Cook and Bakker, 2012, p.100). Zeitoun *et al.*, (2016) describe a reductionist approach to water security helps reduce uncertainty by risk calculation and associate economies to hydro-climatology and socio-political diversity. Their research further state that although a reductionist approach maybe policy friendly, the study undermines it in terms of its inability to reach for social justice. Thereby the study highlights that an integrative approach would help address a broader range of uncertainties and diversities amongst society and environment, and are more likely to reach out to those left behind.

Qualitative indicators primarily depend on an observer's experience and ample data over time to deem a particular place water-secure/ insecure. While these methods use subjective procedures to determine adaptive capacity, there remains a need to compare and quantify inter and intra-scale local conditions and cross-regional comparisons. Adoption of an indicator-based scale and a combined qualitative and quantitative approach varies across the level of research implementation (i.e. more application in a local and regional scale as opposed to transboundary basins) (Gerlak *et al.*, 2018). Hence there is a need for an integrative approach using combined qualitative and empirical evidence and development of essential benchmarks, models, monitoring schemes and place-based metrics. (Varady *et al.*, 2016).

2.2 Characterisation of household level water insecurity

Household water insecurity falls within the dimensions of human development and livelihood. Household-level water insecurity has severe reparations on people's health, psychological stress, well-being, income and lifestyle, social reproduction, justice and human capability (Jepson, 2014; Jepson *et al.*, 2017). Since the inception of the water security framework, many advances have been made in the field of household and individual levels of securing water. The earliest of definitions in a humanitarian framework came from Webb and Iskandarani (1998), "water security is access by all individuals at all times to sufficient, safe water for a healthy and productive life". Following this was previously mentioned the definition of water security by GWP, 2000; which also focused on human development at a household scale through sustainability, ecosystem maintenance and hazards. Grey and Sadoff, 2007 also focused on livelihoods and productive uses of water, while highlighting that water insecurity arises from the negative impacts and inability to increase water productivity. Although these three definitions highlight water security concerning human development, the inability to apply such definitions at a micro-level of local and household scales has also been highlighted by several scholars (Muller *et al.*, 2009; Mudhara and Wale, 2014). Individual-level water insecurity researches led to formation of definitions which focused on the inability to sufficient access to safe and or clean water in adequate amount to lead a healthy lifestyle (Rijsberman, 2006; Wutich and Ragsdale, 2008; Wutich, 2009; Hope *et al.*, 2012; Stevenson *et al.*, 2012). At a household level, scholars further formed four primary dimensions besides water access, namely: quality, quantity and or adequacy, source and or reliability, and affordability (Jepson, 2014; Tsai *et al.*, 2016).

Over time there have been two broad ways of measuring household water (in)security. The first being the use of indices developed, such as those mentioned in Section 2.1 above (water poverty index, climate vulnerability index, water scarcity index, etc.). Additionally, a few more notable indices which pertain to water security are the National Water Security Index (NWSI) developed by the Asian Development Bank (ADB). Besides focusing on economic, urban and environmental security and resilience to water-related disasters, it also highlighted households through its Household Water Security Scale (HWS) (ADB, 2016). Another widely used index is the Water Poverty Index, which was developed at regional and community scales for the multidimensional measure of household welfare concerning water availability (Korc and Ford, 2013). Various other such indices such as the Urban Water Security Assessment Index and Water Security Sustainability Index also focused on a regional scale (Norman *et al.*, 2013; Huang, Xu *et al.*, 2015). Further in addition to such matrices use of census data such as household infrastructure, affordability, basic water requirement as proxies for water security and insecurity at a household and individual scale has been widely used. Irrespective of such prevailing indices, it is argued that most or all of the scales mentioned above are effective for hazard, vulnerability and risk assessment at larger scales. Such scales are unable to capture the lived experiences at a micro-scale of household and individual level, which may significantly vary from within a few households to within the household itself. The indices which work at macro levels are argued to be more policy-oriented at managerial scales and does not consider the complex interactions which may occur at a household level (Jepson, 2014; Jepson *et al.*, 2016; Jepson *et al.*, 2017; Shrestha *et al.*, 2018).

To solve this paradigm, social sciences and public health scholars have put forward the development of community/ micro/ household level metrics. The first of such scales introduced water insecurity in three dimensions of inadequate supply of water, insufficient access to water and dependence on season water sources. The scholars further improved and improvised the same to form an ethnographic experience-based water insecurity scale to understand the variability in water insecurity amongst households within a community and within household members based on gender (Wutich and Ragsdale, 2008; Wutich, 2009). Since the introduction of such a scale based household water insecurity metric, the idea for the same has been debated, improved and is still under improvisation towards the development of a geographically accepted golden framework, which is currently lacking in household and individual level water (in)security measurements (W. E. Jepson *et al.*, 2017). The idea for the development of such a metric had its root based on the significant development made in the field of food security. Comparable scale-based metrics to understand, quantify and evaluate food security through household and individual perception has been a significant development. Such food insecurity scales has allowed for quantifying and assessing risk, prioritizing resources and identify consequences of food insecurity (Alaimo *et al.*, 2001; Sellen *et al.*, 2011). Wutich, (2009); conducted a theoretical approach to formulate a cumulative experience-based water insecurity scale in Bolivia. The scale was used for inferring various associations between water insecurity and seasonality, income, coping strategies and storage capacities. The developed scale helped understand intricate relationships between resource scarcity and mental health. The scale was further used to understand bio-cultural experiences within the household itself, confirming gender disparities extend during the scarcity of resources. Subsequently, several other such scale-based approaches to understand both water security and insecurity has been conducted over the last few years. Extending the notion of the developed experiential scales, scholars further formulated item-based water insecurity scales and validated such scales across various dimensions. With respect to human health, such item based perceived water security scales generated has been compared with globally accepted Perceived Stress Scale (PSS) amongst female household heads and women in Ethiopia and Nepal (Stevenson *et al.*, 2012, 2016; Ahira *et al.*, 2015). While these scales stressed the relationship of water insecurity with certain domains of physical access and quantity of water, they differed significantly to perceived stress. This could be because of the varied geographical locations of these two studies and the varying social, economic, climatic and physical factors that affects them are different. Such variation highlights the fact that perceived emotions vary at a micro-level scale and should be observed and quantified as such. Tsai *et al.*, (2016); further progressed such scale-based approach by formulating 8 items which were valid in the context of rural Uganda. Through cumulative analysis of the developed scale the research highlighted correlation of water insecurity with water source, distance, seasonality and gender. The study also inferred inter household variability through lived experiences thus highlighting the complexity of household water insecurity measurements portraying what might be ‘security’ for one may not be the same for another within proximity. This inference was in line with previous inter-household water insecurity study conducted by Wutich, (2009). Adding on to recognised dimensions of water insecurity Jepson, (2014); furthered household water security metrics by addressing hydro-social variability in low-income peri-urban and rural communities along the Texas – Mexico border. The following study identified three domains of water insecurity under access, quality and emotional distress. It inferred that although all households in the study area had water networks a significant amount of them were water insecure, thus breaking the myth of universal service in developed countries and referred to such conditions as a ‘no-win waterscape’.

Although such significant advances have been made in the scale-based analysis of household water (in)security at a micro level, there remains debate over the inclusivity of developed scales to the overarching view of water security. Quantitative estimations of perceived emotions bring forth finer problems and situations regarding water (in)security in two broad categories: experiential (subjective) and physical (objective). Therefore, the developed perceived scales need to be validated against a wide array of physical dimensions, which may lead to water insecurity in reality within study areas of concern. Shrestha *et al.*, (2018) further promoted this notion through their household water security study. Whereby they developed an ‘Objective Index’ combining various physical dimensions of water security and validated the cumulative physical index against developed micro-scale water security index. Various other challenges remain, firstly with identification of the household itself as a unit of analysis. Secondly, defining the household head and or respondent of the survey who is to provide their perceptions is of importance while developing the scale. As observed from previous researches, it has been established that variations exist within a household itself, between genders and during times of resource scarcity. Hence the unit of analysis itself needs to be established and defined before progressing with such scalograms. Thirdly, formative and qualitative analysis has been observed as an entry point to micro-scale development across all researches. Although the initial process remains the same, the items for analysis remain varied across researches, and so does the recall period for surveys (W. E. Jepson *et al.*, 2017). These challenges although acts as a hindrance to the formulation of a global framework to micro-level household water insecurity scale help affirm the scalar variations which otherwise aforementioned macro-level indices fail to capture when used as a proxy to water insecurity at a household level.

Debates further arise on frameworks to be adopted while conducting a micro-level water insecurity study. Scholars have raised various relation frameworks, most used and important of which are: socio-hydrology, hydro-social cycles, hydro-social transitions and coupled social-ecological systems. Relational frameworks are important to analyse a holistic understanding of water (in)security. Household-level water insecurity research requires an understanding of complex interdependent processes at multiple levels and socio-spatial differences. Such analysis should observe water as both a ‘state’ and ‘relation’ to infer the complexities related to economic, socio-cultural and political dynamics (Wutich *et al.*, 2017). An important correlated dimension that affects water security is observed to be climatic variability (Wutich, 2009; Scott *et al.*, 2013; Pearson *et al.*, 2015; Pearson *et al.*, 2016). Although eco-hydrological and or ecological, and biophysical processes remain unobserved in such scale based relational frameworks. Wutich *et al.*, (2017) questions the feasibility and applicability of such ecological process under the dimension of household water insecurity and identifies a limited concept of ecological changes has been studied within the developed household water insecurity scales. The scholars identify ecological changes as physical processes which are inclusive to social dimension and calls for more comprehensive analysis of sub-domains that govern a changing physical resource and state simultaneously. Another challenge identified and the most pressing one to move forward with the idea of scale-based household water insecurity is the cross-scale geographical universality of the same. It has been observed that household water insecurity metrics have been varying widely across cultures and socio-demographic contexts. Unlike food insecurity, there remains a lack of globally accepted golden scale for household water insecurity at the moment. In light of same, argues that although the development of a universal scale is may be difficult, given the complexity of water resources a valid cross-cultural comparison of such perceived water insecurity scales is required to advance the notion further. Their research further tries to call for an integrative micro-scale for individual and or household water insecurity to synthesize and capture coupled social and hydrological systems at multiple scales, forge interdisciplinary research and advance policy dialogues through required interventions at such scales.

Most researches within the context of RSA, focus on water (in)security as a subdomain of food (in)security, smallholder irrigation and or otherwise agricultural security (Ayisi and Vanasche, 2004; Wenhold *et al.*, 2007; Holmatov *et al.*, 2017). Recent studies, however, have tried to capture a perception based water security at the household and community level. Sinyolo *et al.*, (2014); applied for a perception based micro-scale for water security by item analysis. They derive and formulated a Water Security Index which was checked for water and related food security for smallholder farming households within an irrigation scheme. They identified the developed index as a first-ever approach in the South African context, to the best of their knowledge. Through their developed index they inferred irrigators need to be water-secure to improve their farming yields and subsequent food security. The scholars ultimately highlight the importance of further investigation of various other water security domains (i.e. reliability, sufficiency) to strengthen an empirical analysis of micro-scale water security index. Meissner *et al.*, (2018) and Steyn *et al.*, (2018) further advanced the idea of perception-based water security by conducting a study through interpretive view to understand perception-based water security at a governmental and or municipal level. They combined qualitative discussions that portray an individual's perception of water security in two municipalities of RSA and adopted a casual mechanism approach to understanding the role, opportunities and influence of local governments with respect to individual-level water (in)security. The authors inferred that perceived water security in the study areas is dominated by the biophysical environment of the system, interaction of people and water resources, and interaction amongst people within the system. Their research advances the notion of perceived water security, stating its effectiveness for identifying and enhancing the gaps within a socio-political structure and how policies can be enhanced and practised to improve water insecurity conditions.

2.3 Institutional framework for water in South Africa

South Africa is a nation with a complex water governance scenario. It has had large scale success but also faces multiple ongoing challenges in present times. RSA was at the forefront of policymaking when it introduced its Constitution back in 1996. Within the framework of the country's first framed policies, water was identified as a fundamental human right (REPUBLIC OF SOUTH AFRICA, 2012). This was precisely 14 years before the United Nations (UN) recognised the human right to water in 2010 (United Nations General Assembly, 2010). Such a transformative step reshaped the water landscape of RSA tremendously and put the country globally at the forefront of policymaking. Since its inception, water policies have been reshaped time and again. There exist several inequities in terms of sustainable and adequate access to freshwater resources. The country's evolving water landscape and governance are deeply rooted in its socio-economic conditions and political history in terms of the apartheid regime pre-1994. Therefore, to better understand the development of water policies, the literature review has been broken down into two parts. Firstly, it is vital to understand the scenario before independence during the apartheid times which has been stated by multiple scholars as to the root of the problem, and current disparities are a repercussion of it (Francis, 2005; Earle *et al.*, 2005). Secondly, focus on post-1994 developments and how the country reformed its water policies with progressive measures has been highlighted.

2.3.1 Water governance pre-1994

South Africa pre-1994 was governed under the auspices of the then ruling Nationalist Party. The policies back then were more favourable to a selected few (towards the white South African population) and marginalized the others. The government created control influx policies pushing the black population of South Africa to remote and rural locations leading to the creation of so-called "homelands" (Cole *et al.*, 2017). These places were mostly in arid regions with poor soil, and limited water resources were made available to the population. This led to the development of two different socio-economic groups separately within the same country leading to pigmentation of the society and its resources (Francis, 2005; p 7). Within this timeline, water policies were no exception. Water rights were primarily linked with land ownership rights, whereby the government followed a Riparian policy. The 1956 Water Act which was the principal policy back then focused more on agricultural development through commercial agricultural arrangements and subsidies primarily for the white population and tried to prevent the influx of rural population within urban areas. This led to a dominant group of white commercial farmers who were more privileged in terms of access to water, land and economic prowess. Water resources were hence observed more as an economic good at the expense of social equity. Although unlike other developing countries which were going through agricultural transformations or where agriculture is a prime economic tool, the South African agrarian transformation was distinct. Due to the power imbalance within the country's population and policies which favoured selected few, the transformation created large scale unemployment of the marginalized black South African population. As a result of which the economic disparity amongst the rich, poor and the poorest within the nation reached striking imbalances. Reflection of which is observed till date within the nation's rural economies. The 1956 Water Act further focused on the mining and industrial sector for the nation's economic development through basin management and had "formally declared rivers flowing through homelands as international drainage basins" (van Koppen *et al.*, 2014, p 546). Trading of water was thus encouraged amongst white population owned irrigation farms to use it at its maximum efficiency by ample creation of dams and or private reservoirs to curb water resources. Thus, this period was marked by significantly growing inequities amongst the various societies within the county. While it marked a transition and growth of white South African dominated commercial irrigation, the black South African population within the homelands who were predominantly agriculture-dependent got to use the dire minimum or even less of the country's water resources for their livelihoods and development.

2.3.2 Water governance post-1994

Post the country's independence from the apartheid regime in 1994, and radical changes were made to remove and correct the previously existing social inequities. To correct the wrongdoings of the past and to promote justice and balance within the nation, the newly elected democratic government reformed the water laws in 1998. The ground-breaking and most transformative water policies were introduced via the Water Service Act (WSA) of 1997 and the National Water Act (NWA) of 1998. These two acts were the result of extensive public participation under the constitutional agenda of water for all. Through these acts, water was introduced as a basic right, and this singular transformation made these acts globally as the most progressive laws of the then time. The major transformations as a part of the NWA were progressive in numerous other ways. It led to the creation of a permit system as of which water reallocation was to be done equally within all sections of the society through a permit-based system, thus abolishing the prior riparian policy to water access. The Act thus reshaped the private water ownership by putting the nation as the owner of all water resources and the state as the custodian of it for all citizens. The NWA created a single right to water, calling it the "Reserve" and emphasized on the integrated management of water resources. Thus, the NWA was based on three broad pillars of social justice, economic efficiency and sustainable growth of the environment. Under the 'reserve' a necessary amount of water was to be provided to all sections of societies while simultaneously securing the sustainable amount of water for environmental and ecological growth (Mackay, 1998; Coning, 2006, Earle *et al.*, 2005, van Koppen *et al.*, 2014). Under the dimensions of social justice to water allocation and use, the

NWA further emphasized the availability of basic supply for livelihood and development (water and sanitation) to every citizen.

Through the governments Reconstruction and Development Program (RDP), a mandate to provide 25 litres per capita per day of water was made compulsory through piped water access within 200 meters of every household. The WSA further helped decentralize water resources of the nation by placing the Department of Water Affairs and Forestry (DWAF, now known as Department of Water and Sanitation (DWS)) as the regulator of water resources and the municipalities with the mandate of water provision under the municipalities or local governments. The DWAF took to the following responsibilities of the municipalities in these initial years until the local governments were adapt to it. It also called for the formation of Catchment Management Agencies (CMA) to better manage water within each catchment. The NWA also promoted large scale public participation in decision making, something which was missing previously. This allowed for a greater sense of equity in terms of socio-economic and socio-political growth. Therefore, the country now took to water resources for social growth and equality besides improving its economic efficiency. The DWAF which was in charge as regulators invested heavily in promoting safe and adequate basic access as was promised. For the initial five years till 2000 the DWAF promoted such activities. In 2006 when the municipalities and local governments were defined as formal systems with the constitution, the DWAF handed over the responsibility to the local municipalities. Whereby henceforth these municipalities were funded by the government to provide basic water supply to the communities. Thus, water services provision was decentralized, although the water resources management was still under the central government’s authority. Although such rapid developments were promised and implemented, the country still faces challenges in terms of water supply and access across the rural-urban divide in present times (Coning, 2006; Muller, 2008).

2.4 Climate change and population growth in rural and peri-urban communities of South Africa

Researchers have constantly portrayed the importance of water and food security as key challenges under a changing climatic regime. Globally both these factors are of high vulnerability under continuously changing climatic patterns. Studies have highlighted that global temperatures may increase by 1.4 to 5.8^{o} C by the end of 21st century thus signifying a significant reduction in freshwater resources and agricultural yield. In the context of Sub-Saharan Africa, studies show by 2050 the rainfall could drop by 10%, therefore reducing drainage by 17% and in turn affecting food and water security (Falkenmark, 2013; Misra, 2014). Climate change also has severe impacts on groundwater quantity and quality. Given that globally 1.5 to 3 billion people depend solely on groundwater resources, the effect of climate change and short-term variability is of utmost importance. Global Climate Models (GCMs) and Intergovernmental Panel on Climate Change (IPCC) reports portrays significant changes to average precipitation, air temperature and in turn on groundwater recharge, river flows and global sea levels. Such climate variabilities are predicted to increase in terms of accelerated anthropogenic activities. (IPCC 2008; Kundzewicz and Doll, 2009; Jarvis *et al.*, 2010; Kurylyk and Kerry, 2013).

South Africa is highly vulnerable to impacts of climate change and is marked by increasing frequency and intensity of extreme weather conditions such as floods and droughts. Also, the climate of South Africa is expected to get drier with an increase in such extreme conditions. (Nhemachena and Hassan, 2008; Clay *et al.*, 2003). The South African climate is marked by a predominant semi-arid climate type with significant rainfall variations across years. Climate predictions highlight that such trends may aggravate and continue with wet season increasing and simultaneously causing an offsetting decrease in drier months (CLay *et al.*, 2003). The country has recorded climate related disasters that has caused wide scale damages and sometimes loss of lives. Insufficient and inadequate water service to poor communities is coupled with the country's relative scarcity of national freshwater resources. South Africa has few rivers, no mountain snow pack and a mean annual rainfall that is substantially low than the global mean average. Further extremely high evaporation rates 92% of limited rainfall goes back to atmosphere and 60% of mean annual rainfall can be used as a source of fresh water. Seasonal variability and unpredictability of droughts strain the country's water supply and historical human settlement patterns have led to a geographic mismatch between water availability and water need. Thus, in most populous areas water has to be imported from other basins and some regions are entirely dependent on water originating from beyond their boundaries. The rainfall pattern in South Africa is highly seasonal: the wet season (summer) lasts from October to March, and the dry season (winter) is from April to September. Therefore, the water year is from 1October through 30 September. The mean annual (water year) rainfall is 500 mm (Meissner *et al.*, 2018; Steyn *et al.*, 2018). Additionally, high potential evapotranspiration results in significantly poor rainfall to runoff conversions, wherein the Limpopo and Orange river basins are reported to have an average of 5.1%. Prolonged droughts, which are often followed by sporadic and intense rain events further characterizes the climate in South Africa. Therefore a non-linear relationship tends to exist between rainfall and recharge, wherein highly recharge episodes are limited to anomalous and extreme seasonal rainfall events (MacDonald *et al.*, 2012; Taylor, 2013). Given such high climate variability and dependence of recharge, such episodes can be infrequent and lead to extreme weather conditions such as prolonged droughts. This could lead to water and related food insecurity for population majorly depending on groundwater resources for their survival and sustenance. 74% of the rural and peri-urban population is entirely dependent on groundwater, which constitutes only 9% of the nation's water resource while 19% of the population still lack access to safe water (UNESCO WWAP, 2006).

Besides the highly variable climate there is also an increasing dividend of rapid population growth in rural and peri-urban South Africa. This also has led to an incremental growth of informal settlements in such regions, which further acts as a stressor to climate variability. A vast majority of such rural population being entirely dependent on small scale agriculture, makes such population vulnerable to changing climatic regime. This further leads to physical and socio-economic impacts of climate change, thus affecting the water and food systems. Such determinants of climate is furthered heightened in socioeconomically vulnerable areas and critical sectors such as agriculture, energy and industry (Leichenko and O'Brien, 2002; UNESCO WWAP, 2006; Conway *et al.*, 2015).

2.5 Beyond free basic water: Households willingness to pay for water services in South Africa

Pre-1994 large dividends of the economy were invested towards the agricultural and industrial growth of the country. Hence with the dawn of democracy, when the government decided to provide basic water for domestic purpose, it could only be processed and improved at a cost. Provision of basic water supplies are within the auspices of the central, provincial and local governments combined. Wherein the state should ensure the physical access to primarily poor and marginalized communities within their economic bounds (Francis, 2005; Earle *et al.*, 2005). In the year 2000 to reduce the gap between economic efficiency and equity in terms of water access, the South African government introduced a ‘Free Basic Access to Water’ (FBW) under which everyone is entitled to 25 litres per capita per day of free basic water supply or 6000 litres per household per month for a household of eight people free of charge. It also stressed that no public supply should be non-functional for more than 24 hours and water access should be within 200 meters of households. The FBW was funded by local government revenue and structured water tariffs (Muller, 2008). The introduction of cost recovery through tariffs stirred large scale outbursts in various sections of the country. With the introduction of cost recovery, the price of water increased dramatically on the one hand, and the other created unsustainable growth of existing water infrastructures. The reasons for non-payment of water tariffs till date remains varied between too poor to pay for water to perceiving water as a free resource and blaming the local government for its inefficacy in doing so. This has previously led to wide-scale vandalism of water infrastructure to the prevalence of informal piped lines within household premises (Calfucoy *et al.*, 2009).

With the further development of the country, urbanization, lifestyle improvement and industrialization, the pressure on the local governments to provide access to water is going to increase. Various researches have conducted households willingness to pay (WTP) for water services across rural and urban areas of the country to understand and bridge the gap between local governments and citizens emotion. Both qualitative and quantitative analysis has been done across varied municipalities to realize the current situation. Such studies have been done using the help of census data or through survey data collected from communities. Makaudze, (2016) carried out a WTP across HIV residents in rural communities and inferred people are more prone to pay for improved sanitation than for water, whereby residents stressed more on sanitation access being a more significant challenge than water. Akinyemi, *et al.*, (2018), conducted a WTP for access to potable water for nine South African provinces through available datasets and highlighted positive willingness amongst respondents. Scholars have emphasized WTP studies as an essential tool to investigate factors that explain household payment in a complex water governance landscape, such as in the case of South Africa. WTP via stated choice methods is an efficient approach to investigate, quantify and predict people’s emotions and attitudes to attribute changes in an existing or hypothetical scenario (Louviere, *et al.*, 2000). Such controlled experiments can be useful to understand and comment on the various linkages between households emotions and the functionality of local governments in a particular region.

CHAPTER 3

Description of Study Area

The broad geographical boundaries of my study area are defined by the Hout catchment, Limpopo province in north-east South Africa. The catchment is of prime importance within the Limpopo basin as groundwater abstraction rates for irrigation doubled during 1968 – 1986. A semi-arid climate is prevalent in the area with an annual long term mean precipitation of 407 mm/year. The region is known for its potato cultivation with 63% of the catchment having natural vegetation and 25% agricultural land. Hydrogeological modelling in the catchment has proved the existence of a delicate human-natural system which is highly vulnerable to climate and anthropogenic changes (Ebrahim *et al.*, 2019). The Hout catchment is part of the Limpopo province and contains portions of three separate local municipalities: Polokwane, Molemole (Capricorn district) and Makhado (Vhembe district). The present research focuses on the Polokwane and Molemole local municipalities extent within the Hout catchment boundaries, as shown in Figure 1.

The catchment is located 60 km northwest of Polokwane city, which is increasingly becoming a major economic hub of the country. The Hout river a tributary of the Sand River, which finally flows into the Limpopo river, is the primary river channel within the catchment. The Hout river is an ephemeral river flowing intermittently only after substantial precipitation, primarily in the wet seasons. There is two primary water source for drinking, sanitation and livelihood for inhabitants within the study area: groundwater and surface water as shown in Figure 2. Three communities within the Polokwane municipality are surface water-dependent from the Hout river dam. All other communities are dependent on groundwater. The catchment is also unique in the sense of its vast diversity of inhabitants and livelihoods. It is home to both large scale commercial farmers, and smallholder farmers dived between upstream and downstream of the Hout river.

Additionally, a distinct socio-economy can also be observed between inhabitants of upstream located former homeland rural population and the peri-urban communities downstream. The two municipalities of Polokwane and Molemole under present research scope cover approximately two-third of the catchment and is distinct in terms of each other. While the catchment boundaries of Polokwane municipality were the former homelands pre-1994, the region within MoleMole municipality is marked with large scale commercial farms. The presence of traditional governments in these communities alongside the local municipality pose further challenges to water and land access. Therefore the geographical boundaries of the Hout catchment with varied socio-economics, eco-hydrological and biophysical characteristics under a legal pluralism institutional framework pose for a complex coupled human-natural system in terms of water security.

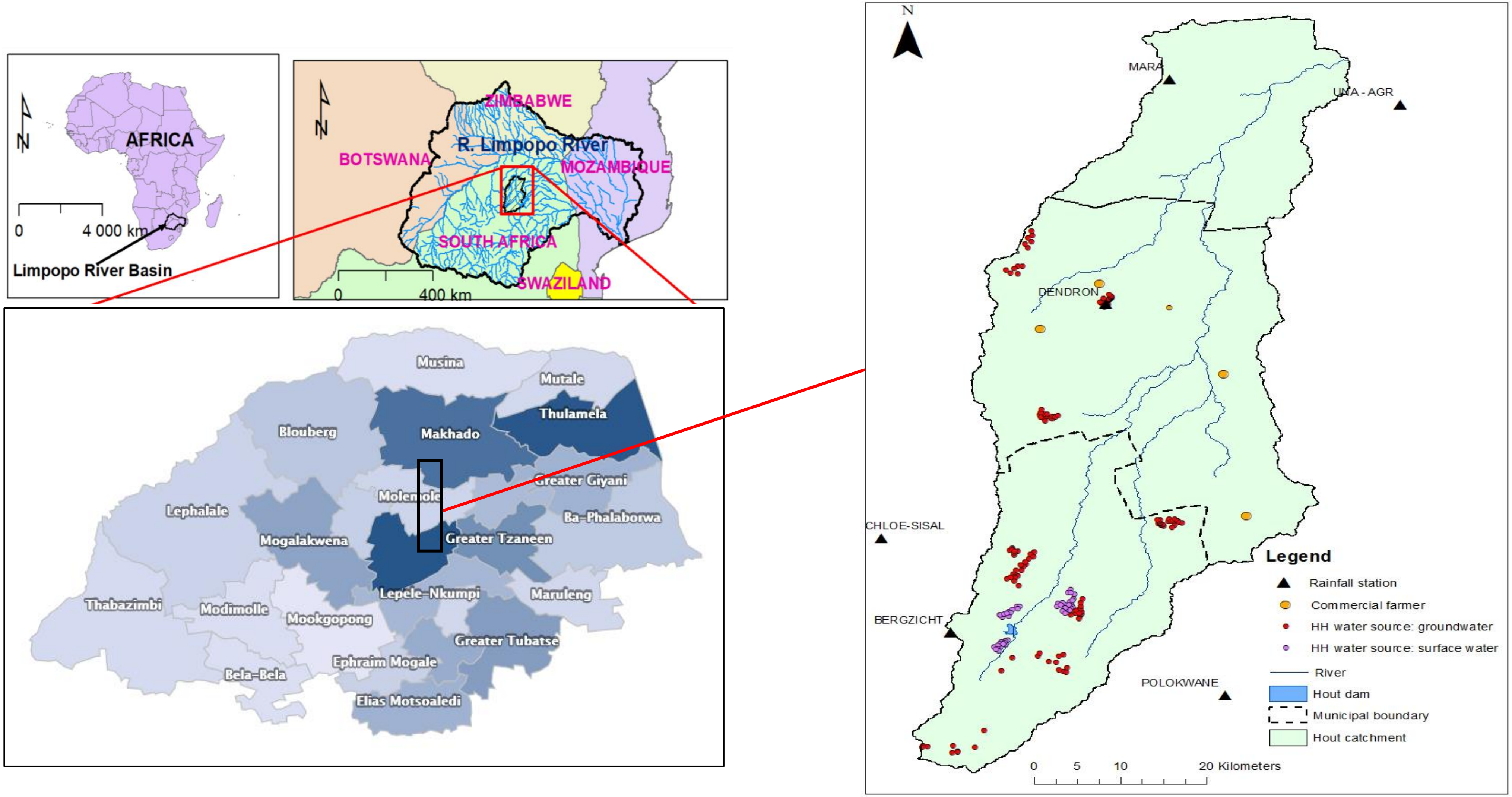

Figure 1 Location of study area within South African local municipalities. Figure shows the surveyed communities, commercial farmers, weather stations used for climate data analysis, the Hout river and dam. (Source: Author, 2019)

Figure 2 Two different sources of water within the rural and peri-urban communities of the study area. To the left is the picture of Hout dam, which supplies water to three communities and to the right is a picture of a groundwater supply system. Water is pumped from the boreholes and stored into on the ground (cement tank) or aboveground (green PVC make tank) and supplied to communities. (Source: Author, 2019)

CHAPTER 4

Methodology

4.1 Research paradigm

Development of a research paradigm through ontological and epistemological consideration is of paramount importance for framing the research flow. It helps in the selection of appropriate analytical methods and subsequent interpretation. Hence the importance of what reality is (ontology), how is knowledge understood (epistemology) and how to find the same (methodology), forms the backbone of any research (Irene, 2011). While explaining a research paradigm, Scotland, (2012), focuses on the necessity of ontology and epistemology in defining a research paradigm through a detailed examination of supported reality and knowledge.

Based on careful consideration of previous literature as highlighted in Chapter 2, I perceive water insecurity as a conjoint result of various dimensions (i.e. social, economic, demographic, political, ecological, hydrological, biophysical, etc.). Additionally, as observed through critiques to advancing water security studies, it is suggested to provide a thorough understanding of a cause-effect relationship through relational frameworks. My study area, in particular, depicts a complex coupled human and natural system with possible recurring feedbacks amongst the various dimensions. To highlight one such view through the research of W. Jepson *et al.*, (2017, p. 47); the scholars say, " each dimension allows us to better contextualize water security beyond just an object (H_2O) to be secured for a certain population". In retrospect, I, therefore, believe in a pragmatic paradigm, wherein reality, which in the case of my present research scope is water security is in a constant state of debate and renegotiation and rise due to a set of actions, situation and consequences, which when not met would lead to a water insecure status. To understand knowledge, I use a bottom-up approach and start with my research problem and questions to understand what tools would be best suited to operationalize and infer on the state of the study system. The research problems I stress on, demands a combined or mixed approach of qualitative and quantitative datasets through convergent parallel mixed methods. Such a method is best explained as the collection of both quantitative and qualitative data simultaneously, which is then integrated to provide a complete picture and conclusion. Understanding of political institutions and processes requires a qualitative analysis of key actors. Climate data analysis requires an understanding of past rainfall data and statistical analysis of the same to understand future trends of eco-hydrological changes. Development of perception-based water insecurity scale and household's willingness to pay requires a qualitative review and quantitative analysis of survey data. Therefore, through a mixed approach, I aim to characterize, analyse and infer on the various pathways to water security and or insecurity. Research methodology in the subsequent section provides a more detailed description of each chosen analysis tools.

4.2 Research design

Defining a research paradigm and approach helps formulate an appropriate path for research design. The research design I have adopted for conducting my research is, as shown in Figure 3. Each subsection and criterions for the multiple dimensions are subsequently described in detail in following Section 4.3. The design I have adopted takes a bottom-up approach by identification of problem statement and thereby formulating research questions and hypothesis. Based on literature study, I have observed two broad views of scholars to define water security: integrative and or reductionist approach. The relational framework under which I carry out my research is that of a coupled human-natural system (CHANS). The definition, therefore, should be one which is best suited for understanding a CHANS. Definition of water insecurity adopted for present scope is based on careful consideration of literature study and simultaneously adopting it to my particular study area. Formulating an adequate water insecurity definition thus helped me choose selection criterions for my study site and also for household survey analysis. Thereby after primary and secondary data collection, I use a mixed quantitative and qualitative approach to analyse my results and reach my conclusion.

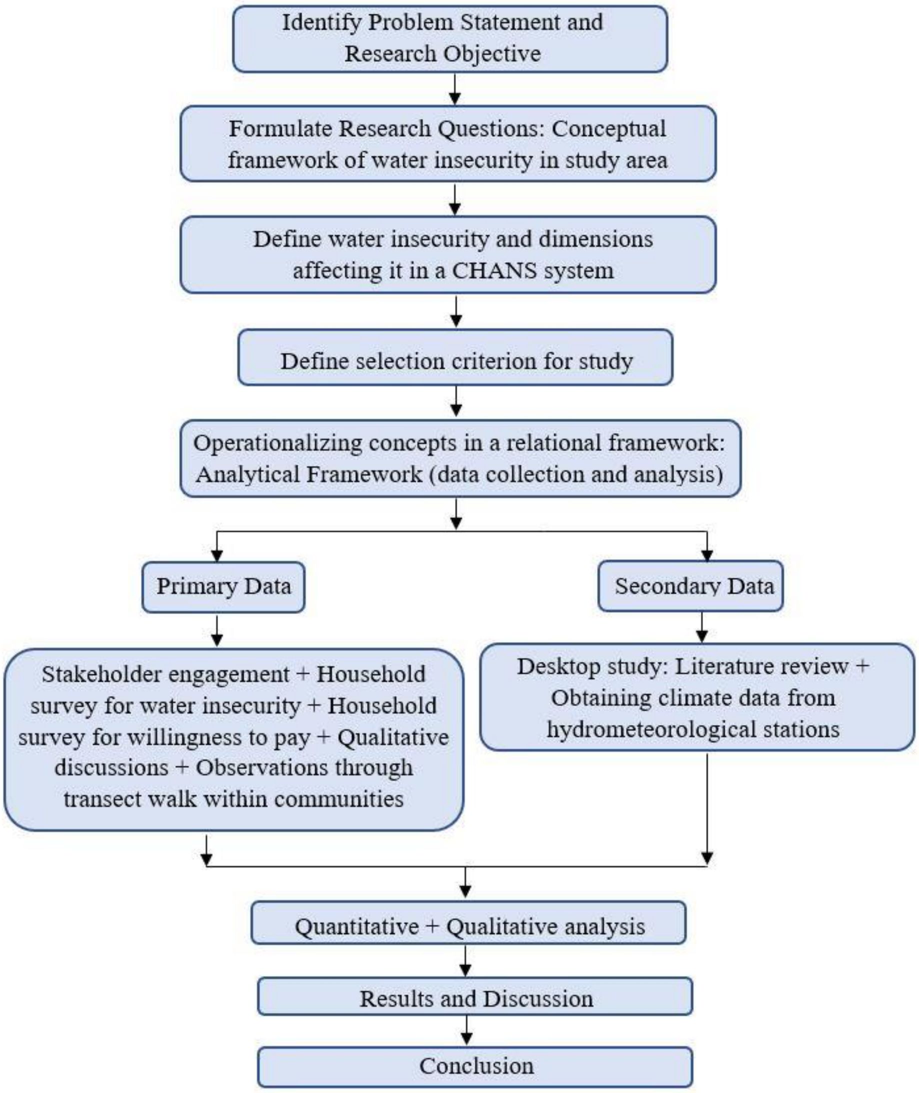

Figure 3 Research design (Source: Author, 2019)

4.3 Research methodology

4.3.1 Institutional framework analysis

To understand in detail the overarching institutional framework of the water sector in South Africa a stakeholder analysis and mapping is performed first. Thereby such approach helps in identifying the relevant stakeholders within the study area and then characterizing them according to their legislative roles, responsibilities and interests. Stakeholders are individuals, groups and organizations that can affect, be affected or perceive themselves to be affected under a specific scenario within space and time. Further, based on face to face structured interviews with relevant stakeholders, the intricate linkages and relationships amongst them are described from a qualitative standpoint. Thereby taking an approach of applying a top-down and bottom-up analysis, I have answered the two sub-questions as put forward in my research objective to highlight:

- The role of local government in water service provisioning and how effective has it been in the study area; and
- The relationship between end-users and local government in terms of water access and use

4.3.2 Climate data analysis

To assess whether the climate in the Hout catchment has changed over time, a trend analysis of daily past rainfall data was conducted. Climate data was gathered from South African Weather Services (SAWS) for five (5) weather stations that are within or close to the catchment as shown in Figure 1 above. Data was collected for a period of 50 years ranging from 1964 to 2015, with one station having 43 years of data. The weather stations are as following: Chloe (23.65°S, 29.07°E; record beginning from 1964), Bergzicht (23.82°S, 29.15°E, record beginning from 1964), Dendron (23.37°S, 29.33°E, record beginning from 1971), Mara (23.07°S, 29.38°E, record beginning from 1964) and Una (23.12°S, 29.67°E, record beginning from 1964). A combination of all these stations was chosen for data analysis as it provides a comprehensive view of the whole catchment climatology, covering a wider area beside the chosen study system boundaries. South Africa has strong seasonal rainfall patterns as observed across a wet season (October to March) and dry season (April to September). Therefore, data gathered was segregated and analysed separately for each hydrological season over time. Climate data as obtained was rigorously checked for anomalies before running statistical analysis. The following exclusions were made if observed:

- Two or more months of missing data were excluded;
- Two or more weeks of missing data during the rainy season was excluded; and
- Data were excluded where the reporting station recorded about missing data and or unreliable data due to missing daily values.

After screening the dataset, multiple linear regression was used to observe and infer trends for the following metrics:

- Seasonal trends over time to check if annual (water year) volume of rain (mm) is changing over time;
- Number of days with rain within each season were checked over time;
- The intensity of rain per season (mm day-1) over time. Where seasonal intensity was measured as a ratio of total rain and number of days with rain (Pryor *et al.*, 2009) ; and
- Climate variability was analysed by comparing coefficient of variation (CV) of monthly total rainfall per season over time.

The statistical analysis was then correlated with perception of climate variability. This was done through a threefold process. Firstly, an initial stakeholder engagement (n=30) was conducted to understand people's perception to climate change. Participants were from the study area and primarily comprised of ward committee members, DWS officials and other non-governmental members. Secondly, I conducted face to face interviews with key stakeholders from the local municipalities, DWS, IGR and CoGTA about the local government's perception to climatic variability. Thirdly, through household survey (n=131), I tried to understand in detail about community's and household's perception to climatic variability. I interviewed both farming and non-farming households within the rural and peri-urban communities of the study area. Also, I spoke to commercial and large-scale farmers (n=5) about their issues and observations to past climate changes. Qualitative data obtained was categorised and analysed as two distinct themes:

- Perceptions regarding changes in weather patterns; and
- Perceptions regarding causes and effects of climatic changes and variability.

Perceptions for climate variability was understood through a brief qualitative discussion whereby respondents were initially asked if they understand climate and climate change. Respondents were also asked whether they have observed any significant changes in climate over the last 10 years. Following this, semi-structured yes or no questions were asked as shown through the survey questionnaire in Section 4 of Appendix B: 'Survey Questionnaire'. Descriptive statistics of the sample size was put together and correlated to analysed climate data to observe and conclude if households truly perceive climate variability, if it hampers their water access pathways and in turn water security and if they have tried to adapt to such variabilities.

4.3.3 Household water insecurity (HWI) scale: Development and analysis of household water insecurity

4.3.3.1 Defining water insecurity

The necessary foundation of developing a research approach lies in the very definition of resource in focus. Based on thorough literature review, I realise that multiple definitions of water security and insecurity are available which are applicable at varying scales. For my particular research, I base water insecurity upon the frameworks of GWP, (2000) and Grey and Sadoff, (2007). These globally accepted definitions focus on safe water, accessibility, livelihood development, environment and sustainability. Such characterizations of water insecurity were deemed to be most appropriate for the present context of a coupled human-natural system. Although the problem with such a broad scale, integrative definitions is that they are not appropriate at a micro-scale. Cook and Bakker, (2012), suggests to operationalize definitions at a local scale a narrowed approach is more beneficial. Microscale studies require evaluation of human perceptions and understanding of their lived experiences. Therefore, a narrower and streamlined definition of water insecurity is more favourable in the present context, one which is quantifiable and can be evaluated. For my present research scope, I conceptualised and downscaled these definitions and applied it to my understanding of socio-economic, political, hydrological and ecological dimensions within the study area of Hout catchment rural and peri-urban communities. The most cited definition of household-level water insecurity is the inability to "access and benefit from affordable, adequate, reliable and safe water for wellbeing and a healthy life" (W. E. Jepson *et al.*, 2017, p.3). For my present scope, I use the same definition and further advance it by adding the dimension of hydrological and ecological changes within the system. Therefore, within the present scope of research, the inability of a household to accept and or adapt to hydrological and ecological changes shall also lead to water insecurity.

4.3.3.2 Criterion for study site selection and data collection

Primary data collection was implemented through a face to face structured household survey at a household level (n=131). Both farming (n=49) and non-farming households (n=82) were included in the sample so as to ascertain varied perceptions of water security and or insecurity. The selection of communities followed two major criterions. Firstly, the municipalities (Polokwane and Molemole) were approached. A consultation with requisite knowledgeable personnel from the municipalities was conducted. The municipalities provided with a map of groundwater and surface water-dependent communities. Additionally, through qualitative discussions the local municipalities also provided a general overview of demographics, water supply distribution systems and situation of water resources of each community. Based on such perspective and consultation 17 communities were selected within the catchment/ study area. Secondly, another consultation at a community level was conducted with respective ward councillors and ward officers. They were asked about community/ village specific water access, use, source and issues. This level of consultation helped understand each community at a finer scale. These two consultations provided preliminary information which guided and informed the development of the survey instrument. The preliminary information was followed by a random walk through the selected communities.

On final selection of communities that were to be surveyed, four enumerators were chosen to conduct the household-level survey. The enumerators included myself, an IWMI professional (knowledgeable in local language Sepedi) and two local level ward committee members (also knowledgeable in Sepedi). A random walk method was adopted by enumerators to conduct the household-level survey within each community. The walk followed a certain rationale which was to start at the dwelling of the ward committee member and or village chief of each community. Enumerators then selected random households each at some distance from one another to conduct the survey. The idea was to obtain as diverse a population as possible and thus, in instances where two households provided very similar responses, the interview was terminated and the enumerators moved on to a different household. The respondent was always the household head. In cases where the household head was absent, the house was skipped and the neighbouring dwelling selected in its stead.

Once the respondent was briefed about the study objectives, the respondent was asked to sign a written consent form. The survey instrument was designed to capture both quantitative and qualitative data through open and closed coded questions. The questionnaire was divided into 5 sections: socio-demographics, perception to water insecurity through pre generated items, water access and use, climatic variability and food insecurity as shown in Appendix B. Section 1 of socio-demographics helped identify household head and household characteristics in terms of age, gender, number of household members, etc. Section 2 highlights the 34 pre generated items/ questions to understand households' perception to water insecurity. I carried out the final survey in the dry month of the hydrological calendar (June) and hence used an accepted recall period of 4 weeks, according to previous researches. I defined the items with a 1 to 5 response scale (i.e. 1 = never, 2 = rarely, 3 = sometimes, 4 = often and 5 = always) and based the items in terms of a respondents recall of a certain experience in last one month (i.e. In last 4 weeks how many times were you unable to access your primary source of water?). Whereby experience was measured in number of days that a particular item has been perceived (i.e. 0 days = never, 1 to 2 days = rarely, 3 to 10 days = sometimes, 11 to 20 = often, greater than 20 days = always). Respondents could also answer to an item as not applicable (NA =6) and don't know or refuse to answer (7). Thus, every item in the initial scale had a scoring option from 1 to 5, with higher scores indicating water insecurity and vice versa. Section 3 highlights physical parameters of water insecurity such as quantity of water collected by household members in litre per capita per day (LPCD), amount of storage available within household premises, number of trips made to collect water, amount of time required to collect water, presence of piped access to water within household premises, etc. Section 4 captures households' perceptions about climate variability, its causes and effects. Section 5 captures households data for food security and or insecurity via the globally accepted Household Food Insecurity Access Scale (HFIAS) (Bilinsky and Coates, 2007; Swindale and Bilinsky, 2018). The HFIAS scale is divided into 9 items questioning access, availability and likeability of food. The scale measures responses in three categories (rarely, sometimes, often). If a household answers to a question as occurring 0 times in the last month (never), then a mean score for that household is not generated. Therefore, the HFIAS scale has a range of 1 to 27, with higher scores highlighting food insecurity and vice versa. All survey data was collected by pen and paper method and notes were taken for qualitative discussions. Collected data was then transferred to MS Excel for better visualisation before conducting data evaluation.

4.3.3.3 Formulation of household water insecurity (HWI) scale

Development of an appropriate micro level, bottom up household water insecurity scale is most crucial to present research scope. A scale can be defined as a reliable and valid indicator of latent constructs that may exist based on the theoretical understanding of the world but cannot be directly measured (Tay *et al.*, 2016). A latent construct may have several underpinned items through which it can be approached. Hence the use of an appropriate scale helps reduce item specific errors and produces the required results through statistical analysis. Boateng *et al.*, (2018), provides a consolidated approach to scale development by identifying three broad categories: Item development, Scale development and Scale evaluation. Similar methodologies for household level water security and insecurity approaches has been used widely in recent literature (Tsai *et al.*, 2016; Boateng *et al.*, 2018; Shrestha *et al.*, 2018; Danielaini *et al.*, 2019). I have adopted and modified the same approach for the current scope of my research, which I describe as following:

Phase 1: Item Development

The first entry point to scale development is through identification of relevant items (questions) that can bring out the latent constructs which are to be measured. Additionally, it is also required to understand and define domains and domain boundaries to a particular scale. For my present research scope, the overarching broad domain is that of water insecurity. Identification of sub domains can either be *a priori* or *posteriori.* The former means that one can identify and categorise domains based on previous literature and or accepted domains which are used in similar scale development exercises, while the later approach leaves identification of domains based on end results of a developed scale (Boateng *et al.*, 2018). In the recent past scholars have identified various sub-domains of water insecurity such as opportunity costs, social interactions, obstacles to water access, perceived safety and sufficiency of water supply, water access, water distress, etc. Although such domains vary widely across geographical extent, rural – urban landscapes and socio-demographic contexts. For example obstacles to water access although relevant in Ethiopia was found to be not applicable in urban Nepal (Stevenson *et al.*, 2012; Jepson, 2014; Ahira *et al.*, 2015). Given this, I take *posteriori* approach to domain identification. Whereby I let my statistical analysis of obtained survey data define domain(s) which may either be unidimensional or multidimensional.

Following domain specification, it is important to understand what items are to be put in a survey to bring forth the latent constructs of perceived water insecurity. I take help of previous literature to understand how items were generated in varied geographical, temporal (driest or non-scarcity of resource timing of survey) and rural – urban waterscapes. Various researches has been conducted which used developed water insecurity scale to test against psychosocial distress, nutritional disabilities, health and agricultural impacts under water availability or scarcity (Wutich and Ragsdale, 2008; Hadley and Wutich, 2009; Fielding *et al.*, 2012; Aihara *et al.*, 2015). Boateng *et al.*, (2018, p.149) best describes item generation procedure to be either deductive or inductive which should be broadly defined and suggests an initial set of items should be twice of desired scale. The researchers further define items should be such that they can be communicated appropriately to a respondent who understands the question and has access and is willing to answer such questions. As expected, based on critical examination of previous literature I understood; while scholars keep several items almost similar in every research, the response rates to items vary in space and time.

Therefore, a stakeholder engagement (n=30) was conducted prior to site visit. As mentioned previously, the participants were from the study area and primarily comprised of ward committee members, DWS officials, some household representatives and other non-governmental members. An initial survey was conducted in the stakeholder engagement to understand people's perception to water security parameters broadly. For example, few key highlights were stakeholders cared about their water security status. Additionally, they highlighted lack of knowledge related to groundwater, inability to access climate and groundwater data, lack of local government support and inability to access and or use sufficient water from time to time, leads to water insecurity. I combined these identified dimensions with literature data and generated a preliminary questionnaire for survey which contained 34 items as shown in Section 2 of Appendix B. The generated item list was rigorously evaluated and modified through expert reviews who had prior knowledge of site dimensions, before I applied the same on field.

Phase 2: Scale Development

Before administering a final survey, enumerators on field (refers to myself and three other enumerators capable in local language Sepedi) carried out a content validity of initial scale items when on field. I chose a random population across 3 communities (n=15) and asked them the pre generated items. The aim of the exercise was to understand if the items/ questions of the survey were clear to respondents. Such ground truthing also helped identify if the items were adequate within the study system and could be appropriately quantified. While conducting the content validity interviews enumerators asked respondents about their perception of the item/ question. Respondents were also asked to provide a detailed view of associated problems if they perceive that a particular item to be of high occurrence. All interviews were recorded with due permission of the respondent.

Following this exercise, no additional items were generated although certain items were rephrased. This occurred due to English to Sepedi (the local language) translations were not valid for certain items. For example, initial item list had two separate question on emotional distress: worry and upset, due to water insufficiency. In Sepedi, both words translate to similar feelings and hence the question was merged into one. Following the content validity after satisfactorily understanding that questions are perceived and quantified by respondents, I carried out the final survey as mentioned above in Section 4.3.3.2 ('Data collection').

Phase 3: Scale Evaluation

Statistical software tools STATA 15, SPSS 25 and R were used collectively to conduct various part and parcel of the quantitative analysis. An initial approach to screening collected data was carried out through descriptive statistics. Surveyed items were reduced based on three categories. Firstly, missing cases, non-applicable and or refuse/ don't know items were first removed. Secondly, statistical correlation via item-item reduction and item-total reduction was carried out to check item variance and collinearity. Thirdly, exploratory factor analysis of remaining items was conducted to evaluate the factor structure within the scale and reduce items if need be. Identified factors were then grouped together to form domains of the scale (*posteriori* approach). Further details on scale evaluation are provided in next section.

4.3.3.4 *Analysis of HWI scale*

Statistical analysis methods used for generation of the household water insecurity scale was that of principal components analysis (PCA). PCA is a multivariate statistical technique used to analyse items and bring out latent constructs without losing information in the process. Exploratory factor analysis further helps in examining relationships between practices correlating to appropriate and actual decisions by determining the adequate amount of items to reproduce the item correlation matrix. (Olea and Abad, 2014). PCA was chosen with varimax rotation to create a new set of ordered orthogonal variables that contains all the information originally collected but summarized decreasing proportion of item variances. The HWI scale was then developed by calculating mean score for every household across all items. Developed household water insecurity scale scores were then used as dependent variable and checked for correlation to various physical parameters (i.e. quantity, time to collect water, piped access to water, etc.) (as collected via Section 3 of the Questionnaire). Multivariate regression analysis was used to check the correlation amongst perceived water insecurity scale and its developed domains to the independent physical variables or proxies of water insecurity. This helped validate the developed scale and in turn infer the key determinants of water insecurity in the study area. Further, I applied the HWI score and HHFIAS scores to check for correlation between water and food insecurity. A stepwise multiple regression with selected predictor variables and controlled for socio-demographic variables was used to best explain the relationship between household water and food insecurity.

4.3.4 Household's willingness to pay (WTP) for water services

Having described the characteristics of water users, how they access water, the various dimensions that affect them and determining the key factors of water insecurity I intend to understand the willingness to pay (WTP) of the households for water services.

4.3.4.1 *Analytical framework*

Various water econometrics approaches can be applied to understand the WTP for any good. Amongst such a wide array the most popular ones are: Contingent valuation model (CVM) and Choice model (CM). Both methods fall under the category of stated preference method, whereby end users give their opinion about attributes presented to them. While in a CVM survey, respondents are presented with a dichotomous choice of whether or not they feel a need to improve an existing service. If the answer is yes, they are further asked about their choice of improvement and presented with a hypothetical scenario to assess their willingness to pay for a service or good (Arouna *et al.*, 2012; Moffat *et al.*, 2011; Brox *et al.*, 2013). On the contrary, the CM method of survey is a generalization of CVM method, whereby respondents are provided with a wider variety of options through choice cards. These choice cards underpin the various attributes that are the various determinants of water demand. After considering and understanding all option respondents thus choose the option that seems best fitted for them. CM model therefore has certain advantages over CVM, wherein respondents are presented with multiple options to choose from rather than a dichotomous choice. Also choice models help in valuation of each attribute and are more useful under multidimensional changes (Snowball *et al*., 2008; Kanyoka *et al*., 2008). Choice experiments additionally can bring out changes in livelihood implications of a certain policy change within a discrete choice framework. Hence given the complexity within a CHANS system and the multifaceted issue of water insecurity, I chose a choice modelling survey. The theoretical base of CM is within the framework of random utility theory (RUT) which hypothesizes that individuals make their choices based on characteristics of a subject along with random components. The random component is generated based on an individual's preference or by the researcher when complete information is not available. The theory therefore confirms that the utility U_{ij} of any individual *i* based on scenario *j* can be segregated into a deterministic component V_{ij} and an unobserved random component ε_{ij}:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \qquad (1)$$

Where V_{ij} can be expressed as linear function of explanatory variable as:

$$V_{ij} = x'_{ij}\,\beta \qquad (2)$$

Where, β stands for a vector of coefficients associated with explanatory variables, which are attributes of scenario *j*, which can include factors such as socio-economics, price, demographics, etc. The individual would thus be assumed to choose an alternative *j* over alternatives *k* if $U_{ij} > U_{ik}$. This in other words also suggests that since socio-demographic variables remain constant for a user presented with'n' choice cards (i.e. income would remain same regardless of choice card attributes and selection), these can be entered as interaction items. (W.H. Green, 2000, Snowball *et al.*, 2008). Statistical analysis of obtained data was conducted via SPSS.

4.3.4.2 Identification of attributes: Forming choice cards

The key to understanding WTP through econometric method is via understanding the attributes that affect the end users most. It is primary to understand the varied and heterogenous community preferences to further improve and increase the local government's water service provisioning. Identification of attributes were based on qualitative findings from household water insecurity survey (through surveys, key informant interviews and stakeholder engagements) and secondary data from Stats SA and from IDP reports of local municipalities. Four attributes were chosen to be presented for choice modelling. They are: quantity of water, quality of water, frequency of water supply and price of water. Table 1 provides a description of these choice attributes along with options provided and expected choice effects from respondents. Choosing these attributes and presenting each option provides for numerous probabilistic options, therefore to reduce possible eminent choices statistical analysis was used. The method of orthogonal projection via SPSS and R was used to derive to a set of 25 alternatives of attribute choices. These were then grouped into 13 choice cards of two alternative sets and presented to respondents. A description of choice card options is presented in Appendix E.

Table 1 Attribute, levels and expected outcomes of choice modelling study

ATTRIBUTE	DESCRIPTION	LEVEL	EXPECTED EFFECT
Quantity of water 	At present, piped water within household standpipes are highly infrequent and not available at all times. Quantities of domestic water usage is highly variable. According to household survey, all respondents reported they would like to use more water than at present if water was available.	• 3*30 litres/ day • 6* 30 litres / day • 12*30 litres/ day • >12*30 litres/ day	Positive
Quality of water 	From household survey, respondents highlighted poor quality of water and high salinity as the major issues. Piped water was also reported to be salty and muddy (turbid).	• Current water type • Treated water	Positive
Frequency of water supply 	Frequency of water within piped households is highly skewed in terms of availability. In most of the surveyed communities' water is supplied once/ twice a week for few hours at limited flow.	• Current frequency of supply • 12 hours/ day of supply • 24 hours/ day of supply	Positive
Price 	Currently all households across the three surveyed communities does not pay for water services whether or not they have a water meter. A monthly tariff could be introduced for cost recovery of water provision and improved access.	• R 0/ month • R 10/ month • R 50/ month • R 100/ month	Negative

(Source: Author, 2019)

4.3.4.3 Data collection and analysis

I conducted the survey across two communities (n=66) where predefined choice cards were presented to respondents. The choice of these 2 communities was made after completing a wholesome household water insecurity survey which provided a holistic view of the rural and peri-urban communities. The two selected communities were the most affected in terms of water as observed through qualitative discussions and observations while conducting transect walks. Of the selected communities, one was groundwater dependent and the other surface water dependent.

- *Community 1: Dendron (groundwater dependent)*
  Dendron is a peri-urban community within the Molemole municipality. 96% households have a standpipe within household premises but the standpipes were reported to be non-functional since months and even years. The standpipes are connected to water meters but households have not been paying as they are on a strike against local government with regards to water provisioning and supply. Source of water is groundwater. Water in standpipe is of bad quality (reported to be turbid, visualy dirty and has strong odour at times). Community standpipes are not metered. The community has a distinct socio-demography with a newly developed RDP housing scheme towards the end of the community. In the RDP housing region, the municipality has provided with community Jojos (tanks) which are filled twice in a week through municipal supplied water tankers. The other portion of the community is characterized by bigger cement houses and economically stronger households. Such households make use of self-bought pressure pumps and boreholes to ensure water supply.; and

- *Community 2: Ga-Mammadila (surface water dependent)*
  Ga-Mammadila is a former homeland community within the Polokwane local municipality jurisdiction. Majority of the households had standpipes and water supply connection within their premises. Some households lacked a private connection. Source of water is surface water from the Hout river dam. Water is supplied from the dam and stored into a central aboveground community tank. Water from this tank is supplied to households approximately 3 times per week (for 15 to 20 hours). Water supply days are infrequent with daily cut-offs and limited flow. Standpipes are not metered and none of the households pay for water. Other sources of domestic water for the community include public standpipes, tanker water supplied by municipality, water from the Hout river (small puddles during dry seasons), private vendors.

Random survey technique was adopted by selecting arbitrary households at a distance from each other within a community. Respondents were always the household head. Socio-demographic information was collected as a part of the survey along with current water use and the last paid amount of water bill (if any). Each respondent was first described about the survey purpose and given a description of each attributes. Following which a brief qualitative discussion was conducted on their perception of each attribute. Four choice cards were then presented to every respondent for getting their preferred options and views. Therefore, the total number of observations collected for statistical analysis were 66 * 4 = 264.

CHAPTER 5

Analysis, Results and Discussion

5.1 Institutional framework analysis: Understanding roles, responsibilities and water access pathways

Based on prior literature review, I obtained a preliminary understanding of the institutional hierarchy in South Africa. I followed it up with the top down, key informant discussions through open and closed-ended questions with varying relevant stakeholders from a provincial to a local level. The primary key informants approached were from the Department of Water and Sanitation (DWS), Department of Intergovernmental Relation (IGR), the two local municipalities of Polokwane and Molemole, the Department of Cooperative Governance and Traditional Affairs (COGTA), the Ward councillors and committee members across the various wards within the study area and the local traditional heads within the communities. Besides the mentioned actors, I also approached technical operators at a community level, community members, smallholder and commercial farmers, and community farming groups. After a thorough analysis, the major identified stakeholders were classified depending on their roles, responsibilities and interests and are as presented in Table xx. The hierarchical implementation of water policies in RSA follows a national, provincial and local level of implementation. It starts with the Central government putting a plan into action which are then approved by the National Assembly and or the parliament and the National Council of Provinces (NCOP). Thereon the DWS, being the custodian of Water Acts, is in charge of policy support and regulation at a national level. The RSA government also had set up Catchment Management Agencies (CMAs) to oversee water management at catchment (regional) level with the involvement of the local communities. Initially, the government envisaged such CMA's to be 9 in number, but not all of them are yet functional. Where CMAs are not yet established or functional, the national government through the DWS regional office undertakes its management functions. Same is the case for the present study area of Hout catchment. At the provincial level the Office of the Premier (OTP), the provincial governments and the Department of Local Governments together are responsible for support, monitoring and coordinating the various municipalities within each province. Further to this, at a local level, the government has established Water Service Authorities (WSA) and Water Service Providers (WSP). The municipalities are the WSAs and responsible for serving their municipal extent of jurisdiction with adequate water services provisions. The WSA’s work under the supervision of the Department of Cooperative Governance and Traditional Affairs (CoGTA). The WSPs are contractually obligated to the WSAs to provide for water and sanitation services. WSPs can be either private, public or the municipality itself. Additionally, the office of Inter-governmental relations (IGR) help maintains the organization and relationship between the three spheres of governance.

In South Africa the DWS is responsible for bulk management of the nation’s water resources under the legislation of the National Water Act (No. 36 of 1998) (RSA, 1998a). The Water Service Authorities (WSA) are responsible for reticulation of treated water to consumers under the Free Basic Water Act (FBW) to provide the citizens with basic water and sanitation (No. 108 of 1997) (RSA, 1997). The local municipalities are given the mandate to make water sources accessible and maintain the free basic water supply. The regional DWS office is in charge of licencing of water permits and overseeing the implementation by respective local municipalities. They also act as fund providers and or donors to help support the local municipalities. The DWS also maintains water monitoring for quantity and quality through privately maintained borewells within the communities of the study system. At the provincial level other governing bodies such as the CoGTA, OTP and the IGR help in facilitating a fluent conversation between the local and national governmental mechanisms. CoGTA and IGR help provide support to DWS for water monitoring (quantity and quality). These two provincial bodies also help the local municipalities with the formulation of the Integrated Development Plan (IDP), through which each local municipality lay out a plan for the forthcoming years. The water service provision within the rural and peri-urban communities of the study area falls under the authority of two local municipalities of Polokwane and Molemole. Both these municipalities are under the supervision of the larger Capricorn district municipality, which is one of the five districts of Limpopo province. For both Polokwane and Molemole the local municipalities are in itself the WSA and WSP. Each local municipality further has a classification of wards, with each ward having a committee member, a councillor and an elected chairperson across the various wards. Besides the democratic structure of governance, parts of the study area, which falls under the former homelands, have a traditional government structure. These communities are under the supervision of both the municipalities along with the chieftaincy of a local village head (Ndona). Under the traditional governance, the village chiefs have the right to land, by which they can offer land to the village and community people for making settlements and farming. Whereas the right to water, water licensing and permitting is under the supervision of the DWS. Therefore, the local municipalities within South Africa are complex systems as they consist of several components such as by-laws and councils that govern them, several funding mechanisms, administrative personnel, structures and properties that interact in non-linear ways with each other. These complex organisations thus act independently of each other, i.e. activities, funding and IDP of one municipality may be different from another. The local governments, therefore, are not coherent units as such but are the bodies which are in closest contact with the citizens at the bottom-most level of governance. Therefore, the local governments form 'the heart of the democratic system' in a post-apartheid South Africa (Zybrands, 2011; Meissner, 2015). Hence perception to water security and or insecurity from individuals are resultant of the functionality and ability of the local municipality's water access, delivery and support systems.

To analyse for the current status of water service provisioning, delivery and infrastructure systems in place, I started by first approaching the DWS and the local municipalities to understand the water allocation and service delivery plans in place. The Polokwane municipality provides water supply to the communities through the Hout river water scheme. The source of the scheme is the Hout river dam which has a capacity of 1664 Kl/day and has a water treatment plant associated within the Hout dam premises. Water from the dam is treated and sent to three of the surveyed communities. In all other communities, the scheme is dependent on groundwater; wherein water is pumped from boreholes, stored in a communal tank/ reservoir and supplied across the community into respective household standpipes. All the communities of Molemole municipality are completely groundwater dependent. Through key informant discussions at the municipality level, I further asked about past and current condition of water infrastructure, alternative strategies of water supply, problems faced and plans of the municipalities. As a bottom-up approach, while conducting a household-level survey, I asked respondents about their perception of water provision through municipalities and their relationship with the local and traditional governance. Based on qualitative discussions, following findings stood out to determine various water access pathways and hindrances:

Population growth affects efficient planning of water services

Population growth is a dominant underlying factor that affects effective provisioning of water services from the municipalities end. Increasing population is a significant driver and pressure to gaining water security. Rapidly growing population and economic growth of the various communities puts increased pressure on the municipality in providing a fluent supply of water over and above the basic water and sanitation. For example, within the study area, a particular community of Jerusalem was identified as one of the most rapid-growing communities. With an overall population crossing over 10,000 habitats in a meagre five years (as reported), the municipality has an even tougher time in provisioning of water supply. A similar trend was observed amongst all surveyed communities wherein an incremental population growth has put pressure on the existing water services. When initial planning and implementation of water delivery and access was made, most of these communities had a minimum number of inhabitants as compared to present times. With increasing population, the demand for water has increased incrementally while the supply in most cases has been declining. Beyond affecting the municipality service provisioning, such imbalance between demand and supply of water affects the life and wellbeing of the people themselves. A member of the local municipality of Polokwane observed such trait as "*one of the biggest hindrances to proper planning*". He further explained that population data of existing communities are generally gathered from census surveys. Such data is often not accurate and hence leads to improper allocation of water resources amongst communities. The communities also perceive population growth as a pressure indicator. There has been a significant increase in the number of informal settlements and family sizes over the last decade. A survey respondent summarised the situation suggesting in the past; there were enough boreholes to satisfy the needs of the whole community and even helped in agriculture. With time, the community and village boundaries have been increased to accommodate more people through Regional Development Program (RDP) houses and informal settlements has been on a spree. Additionally, failing water infrastructure systems and lack of support from local municipalities have made the water landscape of these rural communities a tough one to sustain and grow.

Overdependence on groundwater

For Polokwane municipality, the Hout river water scheme is majorly dependent on groundwater sources besides the handful communities in which supply is through the Hout River reservoir. Molemole municipality is entirely dependent on groundwater for all its communities. This overdependence on groundwater has created further pressure on the natural state of aquifers besides reducing the supply duration and volume across the communities over time. In the recent past, the Polokwane municipality has taken the support of external consultants to identify the regions based on groundwater and surface water delivery possibilities. Based on the key informant discussions, I highlight the numerous challenges to the existing scheme. For the surface water-dependent communities, the treatment plant from the Hout reservoir supplies water into two larger command reservoirs. The water from these reservoirs then is supplied to various communities. Firstly, the present the plant capacity in itself is inefficient to meet the supply-demand allocations across the communities. The local municipality hence has augmented groundwater supplied from boreholes into the reservoir supply network to meet demands in areas which are already benefitting from the Hout reservoir. Such a network supply creates additional pressure for the communities which are solely dependent on groundwater as the borehole supply water gets shared with other communities. Secondly, the local municipalities reported that the existing large command reservoirs (supply tanks) that are present within the study region are never full or functional due to the unequal demand-supply ratios. The scenario in the groundwater-dependent communities faces similar uncertainties when they share water amongst various communities through one or two command reservoirs. Specific groundwater-dependent communities have their command reservoir but still, have other physical and infrastructural issues that prohibit easy access and supply. Irrespective of these challenges, the local government in the future is in favour of augmenting water access and supply through building more extensive command reservoir and network of villages/ communities thus moving away from an unconsolidated smaller community-based water supply system. A ward councillor reported on the over-abstraction and overuse of boreholes identifying lack of maintenance and awareness from both the municipalities and the pump operators in charge at the ground level. The pumps are operated continuously for extended periods, leading to overheating and thus failure of pumps.

Additionally, when reported on such issues, the local municipalities take an extended period to revert and fix such issues leading to periods of uncertain water supply and access in the communities. Also, when a new pipeline network is advanced, no heed is given to existing pipeline systems, and thus another new branch of pipelines is built, leaving some households with more water as compared to others. Besides the quantity of groundwater, the quality of water is another primary driver across all communities. Proximity to open-pit sanitation systems, leaking sewage connections and open dumping of waste are dominant visual traits observed that could degrade groundwater quality. Besides over-reliance and over-abstraction of groundwater in itself can lead to poor water quality. Communities reported of highly turbid water with a pungent smell and high salinity across the study area. The abstraction of groundwater is also majorly done by the large-scale commercial farmers within the study area. Although the commercial farming zones are downstream to the rural communities, the imbalance on an already stressed aquifer would further enhance the challenges in terms of resource provision if not managed and controlled.

Existing rift between local municipalities and traditional governance

The presence of multiple legal systems characterises the South African politics and society even at the present times. Besides the local municipalities, the rural communities which fall under the former homelands have their traditional governance structures. Under such legal pluralistic conditions, access to water resources is more challenging and complex for communities as compared to other parts of the country. Coexistence of both these structures is divided legally on the grounds of land and water rights. While the local municipality is responsible for water supply and socio-economic development, the land tenure falls under the local village chiefs (Ndona) being the custodian of such state-owned lands. Therefore, a close association between both these governance structures results for a fair negotiation to accessing water resources amongst the rural communities. The key informant and survey interviews highlight the existing gap. A significant lack of trust and co-operation exists between both these parallel governance mechanisms, and the communities are in a constant struggle divided within such power dynamics. Of the surveyed communities, respondents showed a divided trust amongst the local chiefs and the local municipality. Favouritism amongst chiefs and supporting a selected few are common traits within the rural communities of the former homelands.

On the one hand, as the chiefs provide access to more land to farmers and building houses, on the other, the municipality struggles to keep up with water access and service deliveries to the increasing population and demand. According to the local municipalities, although the local chiefs are under no restrictions about segregation of land, there exists limited co-operation amongst the traditional governance and the municipalities. Even after constant negotiations, there appears a distinct gap in lack of trust, with each party wanting to imply its power over the other. Respondents highlighted how both institutions compete to gain more authority above one another and are further driven by their political motives. Household respondents were observed to be divided upon which of these institutions to put their faith. Some respondents shared more interests with the local governance structure, highlighting chiefs have more power and authority to call in the municipality when situations are tough. While another group of respondents suggested, local chiefs have lost their authority over the past decade. They preferred to approach the local municipality through the locally based ward committee members more.

Although regardless of whom they approach almost all respondents showed their dissatisfaction equally towards municipality delivery, access and efforts in maintain water infrastructures. Besides, although extended lands may be available within the communities, the chief’s division of land may be driven by motives of favouritism, monetary valuation and not for the overall growth of the community as such. Such traits could also result in significant lack of ambition amongst the smallholder farmers. Smallholder farmers were majorly observed and reported to grow maize (rainfed crop), and a couple of farmers grew other cash crops such as cabbage, potato, spinach and beetroot. Farmers reported that they mostly use their yield for the subsistence of their households and lacked the finance, will and motivation to move into significant scale developments. Smallholder farmers also lacked unity amongst themselves wherein they do not have any farmers union and or association and lack access to proper credits and extension services. When faced with problems and uncertainties, individual farmers approach the separate governance at their own will. Therefore, to solve an issue, it takes extended periods, thus further affecting their livelihood and wellbeing. For example, a community farm within the study area was started almost seven years ago through a farming scheme under the municipality. Twenty-seven farmers were jointly given a total of 22 hectares of land by the local municipality of Molemole. Each farmer irrigated their land separately through one borehole as set up by the municipality. Twenty-five of the farming members were female, and 2 were male. The community farm stopped irrigation three years back as the borehole stopped functioning. Since then the farmers have had approached both the local chiefs and the municipalities but with no solution. The families who were once both water and food secure now are without any job and depleted quality of life. Presence of multiple departments and hierarchies within the local municipality makes it even harder for the community members to keep track and get to a conclusion with a particular issue. Amongst such competed governance the rural communities can be best described in a situation of a prisoner’s dilemma, wherein they have access to land without water and or vice versa.

Lack of awareness amongst end users and vandalism of existing water infrastructure

Besides the presence of the various water infrastructure systems and delivery networks within the communities at present, these infrastructures are regularly under theft and vandalism issues.

The key respondents from the municipal level and also the community respondents reported loss of transformers as the most common theft across all surveyed communities. While the municipalities understand and acknowledge theft and vandalism of infrastructure as a growing concern, significant measures they have implied has not been able to stop such acts. Pump houses are often at a distance from the communities, leaving it unmarked and vulnerable to acts of vandalism and thefts. The pump operators in charge of maintaining the pumps are also unaware of vandalism issues. This issue also highlights the underlying factor of public awareness and participation. The municipalities reported they had conducted no public awareness programs in the recent past. Consultancy projects also had the missing aspect of public participation. Survey respondents had a wide array of responses on being asked about attending municipal and communal meetings. Although both male and female participants are allowed to join such meetings, more attendance of male as compared to females was reported by survey respondents. Some households reported being not told about municipal meetings as they live farther away and only selected households to get an invitation. People who attend such meetings reported that these events are occasionally organized but mostly limited to the mitigation of varied conflicts as compared to water issues. Mostly the agenda of such meetings is limited to the village chiefs and ward committee members providing top-down information to the community members. Respondents reported that when they raise issues about water supply, those go unheard or are not responded to by concerned authorities. Ward committee members although explained a different scenario and highlighted the rare attendance of community members in such meetings. People also pre conceive such meetings to be political agendas wherein they associate the focus of a meeting depending on the political affiliation of the member who invites them. Youth motivations also play a significant role and are driven strongly by political frameworks. Therefore, the community meetings more often are diverted from people’s issues of water into personal motives of a selected few. In the peri-urban communities, given the nonexistence of traditional governance, municipal meetings are more focused on people’s concerns. For example, in Dendron, the Molemole municipality helps the RDP communities through regular deliveries of tanker supplied water. Although the municipality maintains its obligations in providing the community with the water access, further issues arise that affect wellbeing and water security of households, which i will explain in subsequent chapters.

Failure of cost recovery

Cost recovery of water services is important to sustain and improve the water supply and access to the rural and peri-urban communities. Although certain communities have metered standpipes, the local municipalities in the study area struggle to collect regular water tariffs. The idea of FBW has further created a sense of water as a free basic commodity amongst the rural households, who are against the idea of paying for water services. A local municipality member observed the cost recovery mechanism as, “important step for consumption and conservation control”. Further stating that the local municipalities need finance to improve water supply networks in the near future and does not have an “endless pocket”. Most of the rural communities in the study area have always had meters but the rate of non-payment has been significant irrespective of households being billed. Although no interventions had been made by the local governments due to such non-payments. For a sustainable growth in the future, the local governments are deciding to implement prepaid meters (smart meters), even in the rural communities. Such meters would work similar to electricity supply, wherein a citizen can buy a particular amount of water supply at a flat rate.

Table 2 Stakeholder roles and responsibilities

STAKEHOLDER	ROLES	RESPONSIBILITIES	INTERESTS	PROBLEMS FACED
Department of Water and Sanitation (DWS)	National level: Custodian of the Water Services Act and National Water Act. Primary authority to oversee, implement and funding of water policies as laid out by the central government.	Responsible for water sector policy implementation, support and regulation. Also helps local municipalities with funds for water provisioning.	Highest interest in terms of water allocation and overseeing policy implementation across the country.	Funding, coherence amongst local governments and smooth implementation of Acts.
Office of the Premier (OTP)	At provincial level helps in co-ordination amongst the various national and local government level for coherence.	Helps facilitate amongst the DWS, DWA (Department of Environmental Affairs) and local municipalities.	High interest to bring all stakeholders to an agreement in lieu of development and support mechanisms.	Diverse interests amongst local governments, traditional governments, DWS affects a smooth coherence and its implementation.
Department of Cooperative Governance and Traditional Affairs (CoGTA)	At the local municipal level helping local governments with infrastructure grant.	Involved in Integrated Development plans (IDP), which include Water sector development plan (WSDP) for local municipalities.	High interest to help local municipalities in effective planning of way forward related to water access and provisioning.	Procuring enough monetary support and lacks coherence amongst the diverse local governments.
Department of Intergovernmental Relations (IGR)	Helps communicate between the government officials and politicians at a local scale (e.g. mayors and municipal managers).	They look at the empirical evidence of groundwater issues, regulates WSA and acts as facilitator between local, provincial and national bodies.	High interest to facilitate all governmental bodies from national to local levels.	Lack of coherence across governmental bodies in different levels.

Department of Agriculture	Helps for agricultural growth across municipalities and districts.	Provides funding, awareness and helps in allocation of water resources along with DWS.	High interest to provide economic growth and related water and food security.	Lack of support mechanisms in terms of providing weather forecasts, early warnings and database maintenance.
Traditional Governance (village chiefs/ Ndona)	Custodian of state-owned land across the former homeland communities.	Responsible for land allocation within former homeland communities.	Localised interests as per respective community's growth.	Lack of unity amongst the various traditional governments and lack of trust with local municipalities.
Water Service Authorities (WSA) Water Service Providers (WSP)	Responsible for ensuring water services provision within area of jurisdiction regulated by CoGTA. Can be public/ private/ mixed/ municipality itself provides water/sanitation services as appointed by DWS.	Supply and provision of water to communities as per Free Basic Water Act and beyond to support the multiple uses of water for societies.	High interests in terms of water service provisioning and access across all communities. For the study area, the WSA and WSP are the local municipalities of Polokwane and Molemole and also the Capricorn district municipality.	Lack of coherence and unity with traditional governance, population growth, climatic variability, lack of maintenance of existing water infrastructures further affects water access and provisioning across communities.

National NGOs and INGOs	Public awareness amongst stakeholders.	Help create public awareness and fluent stakeholder engagements.	Localised interests as per scope of work.	Treats communities as one, whereas varied interests are present at local levels (e.g. diverse interests of smallholder farmers).
Private Sector (e.g. Industries)	Economic growth.	Industrial development via water and food security.	Medium interests as per scope and economic growth opportunities.	
Donor organizations – (EU, AFDB, WB, etc.)	Sustainable development, economic growth and development of social wellbeing.	Helps provides funding for projects and support.	High to medium interests depending on project scope	Lack of follow up mechanisms.
Commercial and smallholder farmers	Economic development and improved and equal socio-economic growth.	Water and food security, economic growth for one and all.	Medium to low depending on personal interests.	Lack of unity across the various entities. Lack of trust on local governance.
Households/ Communities	Economic development and improved and equal socio-economic growth.	Water and food security, economic growth for one and all.	Medium to low depending on personal interests.	Lack of unity and trust on local governance, traditional governance systems. Lack of awareness.

(Source: Author, 2019)

SUMMARY

This section highlights the various institutional frameworks and organisations in place with respect to water service provisioning and access to the study area communities. It portrays the roles and responsibilities of each stakeholders and their varied interests. Based on a combined top down and bottom up stakeholder engagement, this section brings out the perceptions to water access and issues concerning such at present times. Rapid growth of population, increasing number of informal settlements lead to mismanaged plans on the local municipalities. Further the overdependence on groundwater sources leads to depleted or high pressure on the aquifer systems. Presence of plural legalism governance structures affects the rural communities mostly whereby they are water without land and or the other. Lack of awareness amongst end users and lack of trust on both governance structures further leads to conflicting situations leading to vandalism of existing water infrastructures. A dominant lack of interest to pay for water services and perceiving water under a free resource further prevents the local municipalities from cost recovery leading to delayed and or ineffective operation and maintenance of water infrastructures and developing better water access. Thus, all stakeholders were observed to affect each other based on their actions and consequences. The next section dealing with climatic variability would further help explain the effect of a highly variable semi-arid climate on such actions and its feedbacks over time.

5.2 Climate data analysis: Understanding future effect on water service schemes and adaptive capacity of communities

Multiple regression analysis of past climate data produced significant time series trends. Trend analysis conducted is as shown in Figure 4. Regression results are as shown in Table 3. Seasonal total rainfall since 1964 was observed to show a significant decrease in both wet and dry seasons (R^2 = 0.74, $p<0.001$, Model 1). The number of rainy days since 1964 has also decreased across the Hout catchment. Significant decrease in the total number of rainy days was observed to be more significant in the wet season as compared to the dry season (R^2 = 0.93, $p<0.001$, Model 2). Seasonal rainfall intensity also showed a significant increase across time in both wet and dry seasons (R^2 = 0.88, $p<0.001$, Model 3). Since total rainfall has decreased, the increase in rainfall intensity is driven by the decline in the number of rainy days across both seasons. Variability in seasonal rainfall has shown a more significant increase in the dry seasons as compared to the wet seasons. Although a significant increase is observed from multiple regression (R^2 = 0.56, $p<0.001$, Model 4), it can be inferred from the statistical trend analysis of past climate data that the overall climate in the study area is highly variable and extreme. Increasing rainfall variability and intensity marked with a significant amount of decrease in total rainfall and number of rainy days per season points out to more sporadic climate events. Both the wet and dry seasons across time has shown sign of a drier number of days, indicating higher extremes of infrequent floods and droughts in the Hout catchment study area. All graphs were plotted using ggplot and analysis were conducted using statistical software R. The scripts used are as shown in Appendix A.

Perceptions to climate variability and its effect on water services

Survey data from stakeholder engagement conducted before site visit was first used to understand the primary concerns and perceptions of people from the study area towards climatic variability. Further to that, data from the questionnaire survey and qualitative discussions through open-ended and closed-ended questions conducted on-site were used to understand in detail about perceptions of community members and households to climatic variability. I also conducted qualitative discussions with key informants from the local municipalities and other relevant stakeholders.

From the stakeholder engagement, 30 survey respondent’s data (22 males and 8 females) were used for initial analysis before the site visit. Most participants (38%) were within an age group of 20 to 40. Amongst the survey respondents in the stakeholder engagement, 47% of people responded to having a good understanding of what climate change is and that climatic variability is vital to water and food security. Although respondents perceived the importance of climatic variability, they highlighted the inaccessibility to adequate climatic data. 67% of respondents portrayed TV and radio as the most viable means to get access to climate news and updates. 70% of stakeholders highlighted that they have no access to climate and water management data in their region. Stakeholders in the engagement meeting also highlighted issues on inadequate training and little to less participatory meetings.

Data from the household questionnaire survey indicate that 87% of respondents across the study area have been aware of significant changes in weather patterns over the last ten years. A significant proportion of farming households (87%) responded positively to observing and facing variability in climate regimes. 95% of households responded to having faced a drought situation over the last ten years, and 72% respondent said to have faced a flood in the last ten years. Respondents highlighted the significant decrease in rainfall event, which lasted approximately eight or nine months in the year 2015 as the most recent drought event in the study area. The most prominent flood event recalled by respondents was in the year of 2003, where more than four months of extreme rainfall led to the disruption of socio-economic wellbeing of the communities. Small scale subsistence farming household responded to such events leading to loss of crops and negatively affecting their farming outputs, leading to loss of household incomes over extended periods of months. Households lived experiences also highlighted such events lead to human and livestock diseases due to over-dependence on unsafe sources of water such as rivers and ponded water bodies, and significant damages to infrastructure and community water sources. Farming households concurred to receiving shorter rainfall events in the recent past years as compared to a historical trend of rainfall. They also highlighted that short-lived extreme rainfall events lead to farming yield depletion and economic losses. A particular smallholder farmer who grows maize, cabbage, beetroot, potatoes on his irrigated plot of 5 hectares at a distance from his household perceived the most drastic effect of climate change as delayed rainfall and decrease in the number of rainy days. He highlighted in the recent past, the onset of the wet season has been delayed from October to Mid-November and ends earlier than expected around Mid-January or February, as compared to March or April. 82% of households responded to a perceived increase in temperature over the last ten years. With regards to temperature changes, household respondents shared their sentiments of facing slightly warmer winters in the recent past. 69% of household respondents also showed positive responses to rapid changes in green spaces around their communities, due to deforestation and rapid increase in population densities in the last ten years. Smallholder farmers also concurred to change in groundwater levels over time. The most highlighted notion was increased sporadic rainfall events leads to a rapid increase in their groundwater levels, whereby increased productivity of their borewells help them increase their farming produce effectively.

On the contrary, households having their boreholes within their premises for their wellbeing did not perceive much changes in groundwater levels. Such boreholes were approximately 70 to 120 m bgl (meters below ground level) and more or less 25 to 30 years old. 28% of households had borehole within the studied sample size. Although some of these households highlighted about having issues with the proper functioning of boreholes due to depleted groundwater levels and pumps running dry and or going up in the air during dry summer months. Households also reported significant deuteriation in groundwater quality over time, with higher salinity during drought and flood events. Farming and non-farming households in the rural and peri-urban populations perceived lack of access to climate and weather information as a significant challenge. Farming households seemed to be most affected by short and delayed warning periods of random climate events of floods and droughts. 87% of farmers responded, saying they are primarily dependent on TV and radio for receiving such news while a few minorities of farmers responded to using mobiles. Smallholder farmers have no farming unions and associations across the study area communities, and a lack of unity and trust is pronounced amongst such entities.

Further majority of them answered favourable to attending municipal and communal meetings but highlighted climate changes are not an agenda of such meetings. Farming and non-farming household perceived climatic variability strongly and seemed to understand the idea of climate changes and acknowledge its effects. Irrespective of their understanding a vast majority of household respondents were unaware of the cause of such climatic variability. Amongst perceived stressors of climatic variability, the most pronounced was deforestation and population growth. As the most pronounced adaptive measure, 24% of households concurred to relocating, and 12% responded about changing their income sources to earn more and prepare for uncertainties. Additionally, 37% of households agreed to have bought additional water storage mechanisms as an adaptive measure, and 88% of households agreed to have adapted by reducing water consumptions and increased sustainable use of water in recent past.

Amongst the surveyed commercial and or large-scale farmers, a varied response to perceptions regarding climate variability was observed. Commercial farmers as opposed to small scale and or smallholder farmers are more technologically advanced and knowledgeable about climatic issues and news in general. Such farmers plan their produce and give more heed to the finer details of irrigation to increase and maximise productivity. Thus, all the commercial farmers interviewed portrayed the importance of climate variability and long terms effects of climate change on their irrigation practices. Regardless of such technological advances, commercial farmers univocally portrayed various challenges to irrigation due to climate variability. Given the perennial nature of the Hout river, commercial farmers are primarily dependent on groundwater aquifers. All farmers agreed that the hard rock aquifers within the study area are primarily dependent on extreme and high rainfall events for increased recharge and also highlighted the role of land use, the slope of the terrain and local geology in such recharge activities. All the commercial farmers interviewed highlighted having noticed changes in climate in the last ten years. Commercial farmers concurred to collecting ecohydrological data such as rainfall through rain gauges, temperature and a few farmers collect groundwater monitoring data. Perceptions of climatic variability included having realised delayed arrival of rainy and or wet seasons, increasing average annual temperatures over the year and decrease in the number of rainy days. Two of the interviewed commercial farmers also highlighted having issues of groundwater depletion across their farm zones, and all farmers portrayed significant depletion of groundwater over the last ten years. Most commercial farmers agreed to depletion in groundwater tables to be a combined effect of climatic variabilities in time and space and over-abstraction of water. One of the interviewed commercial farmers stated that borehole management across commercial farm zones could lead to increased groundwater levels over time. The commercial farmers' perceived climate changes to be a combined result of anthropogenic and natural activities. Local municipalities and key informants highlighted managing climate variability effectively to be one of the most important criteria to improved wellbeing and socio-economic growth.

SUMMARY

This section highlights the statistical analysis of past climate data and compares it to stakeholder's perception to cause and effect of climatic variability. Through regression of past climate data and trend analysis a highly variable climatic regime was observed. Decrease in seasonal total rainfall and decrease in number of rainy days was pronounced. A highly variable rainfall during drier seasons as compared to wetter seasons further confirms the events of sporadic and uneven rainfall which are not beneficial to the communities and farmers. Qualitative results further highlight the same through perceptions across stakeholders. Climate variability and stress has been observed widely across all study area communities. The reported effects of such were mostly decreased number of rainy days and delayed arrival, early retreat of wet seasons. Commercial farmers further validated the effect of climate on the aquifers. Groundwater depletion is thus an overarching result of varied factors besides climatic variability. Local municipalities agreed to the recent possible threat of climatic variability although lacks public awareness programmes at present. Therefore, climatic variability shall put further stress on existing groundwater dependent communities in the near future.

After having studied the effect of institutional frameworks and climatic variability on water access across the study area communities, in the next section I determine the factors and pathways to household water insecurity through people's lived experiences.

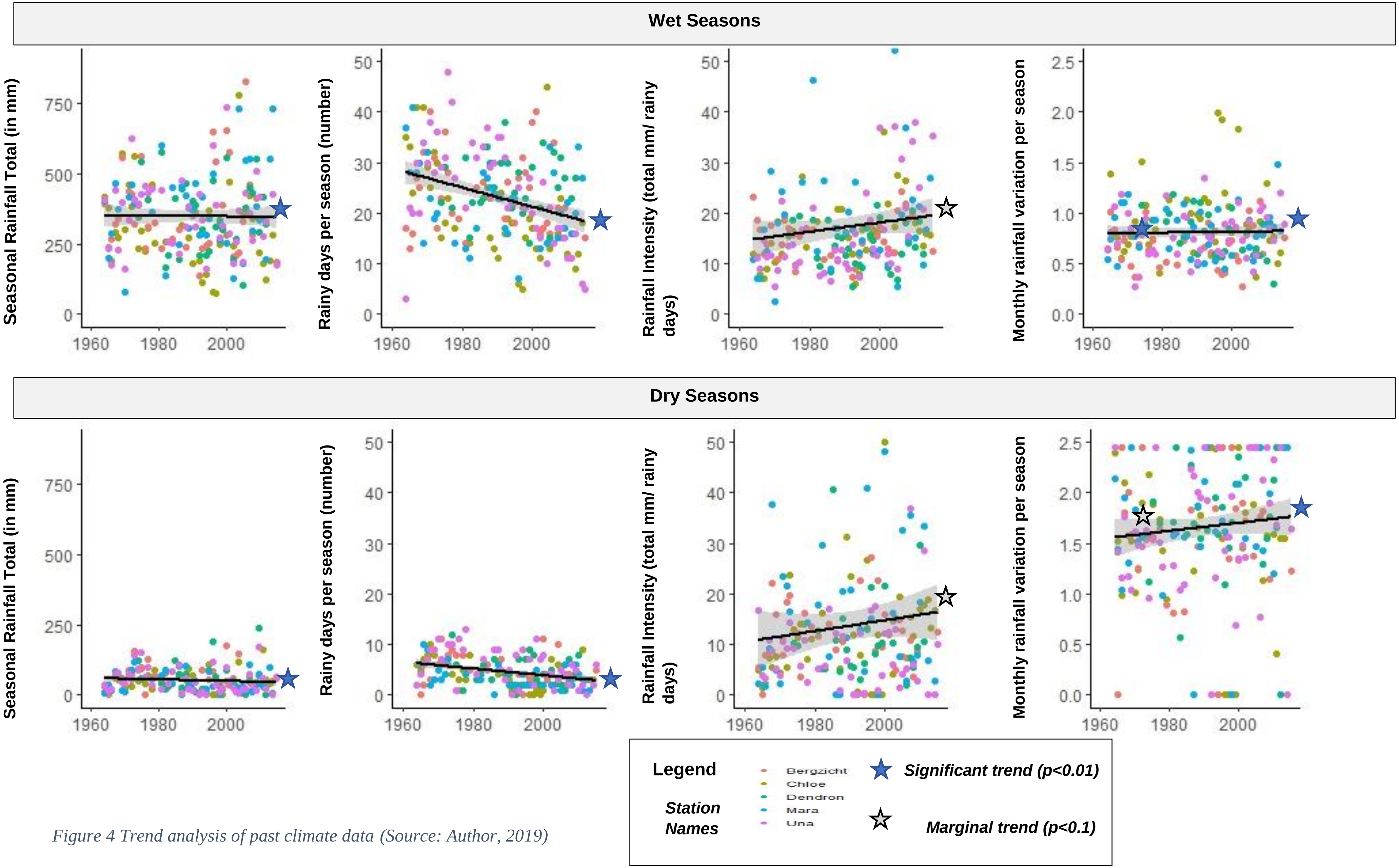

Figure 4 Trend analysis of past climate data (Source: Author, 2019)

Table 3 Multiple linear regression results of climate data from five weather stations

MODEL	ESTIMATE	SE	P	ADJ. R2	MODEL P
MODEL 1: SEASONAL TOTAL RAINFALL (ref: Dry seasons)					
Intercept	154.88	119.85	0.16	0.74	<0.001
Year	0.086	0.061	0.19		
Wet Season	1.064	0.045	<0.001		
MODEL 2: NUMBER OF RAINY DAYS (ref: Dry seasons and Una station)					
Intercept	502.715	196.964	<0.05	0.93	<0.001
Year	-0.250	0.097	<0.05		
Wet Season	1.146	0.118	<0.001		
Bergzicht Station	-0.002	0.158	<0.001		
Chloe Station	-0.081	0.186	<0.001		
Dendron Station	0.191	0.214	<0.001		
Mara Station	-0.085	0.195	<0.001		
MODEL 3: INTENSITY OF RAINFALL (ref: Dry seasons and Una station)					
Intercept	33.95	42.45	<0.1	0.88	<0.1
Year	-1.737	2.13	<0.05		
Wet Season	4.316	1.26	<0.05		
Bergzicht Station	-1.003	1.65	<0.05		
Chloe Station	-1.731	3.59	<0.05		
Dendron Station	-1.155	3.34	<0.05		
Mara Station	-3.701	1.44	<0.05		
MODEL 4: RAINFALL VARIABILITY (ref: Dry seasons)					
Intercept	-33.39	38.14	<0.1	0.56	<0.001
Year	0.018	0.019	0.35		
Wet Season	2.231	0.275	<0.001		

(Source: Author, 2019)

5.3 Beyond water access: Determinants of household water insecurity analysis

5.3.1 Household demographics, socio-economic characteristics and ecology of water access and use in study area

The total sample size after completion of the survey was 131 households. Survey data of eight (8) households were rejected from the final analysis due to incomplete survey and or disruption in the survey (i.e. respondent leaving in between the survey procedure). Besides conducting item analysis through perceived water insecurity scale questionnaires, descriptive data were obtained and used for further validation of HWI scale and understanding determinants of water insecurity. Such data helps in characterising the household's socio-economics, demographics, and understanding the physical characteristics of water use and access. Table 4 portrays the descriptive analysis of continuous and categorical variables as obtained from the survey. The sample characteristics, as gathered, were divided into four categories as following:

Respondent characteristics

Household heads interviewed were mostly experienced people (either female/ male) who had a proper understanding of the household's water status and problems. Of the total sample, 70% were female, and 30% were male. Female household heads were thus common within the study area with more knowledge of household characteristics as compared to males. The average age of respondents was 49 years. Education level was observed to be reasonably high within survey respondents (household heads), with an average of 10 years of education (Secondary education level). The two main languages spoken by respondents were Sepedi and English, with n=54 (44%) respondents who could speak both languages.

Household demographic characteristics and financial resources

On an average household size was observed to be of 5 people. Household income obtained during the survey was as a lumpsum average amount for the household. Some respondents (n= 12, 10%) refused to answer. In general, an average income of 2400 Rands was observed across the survey, although most households lived on social grants as obtained from the government. These grants were in the form of health, education, HIV support and various other social supports such as children's education grant, pensions and disability grants. Some households portrayed higher income status due to support received from children and relatives who provide monthly financial support. Eighty-seven households were observed to obtain some social grant. Most households had a male member (n=34, 28%) working. Employment status varied from being a ward committee member, shop owner, mechanic, school teachers, government and private jobs. Water affordability was measured as a ratio of total expense on water resources per month to total household income. The percentage of monthly income spent on water (i.e. buying) was compared with a conventional affordability ratio (CAR). Such CAR's vary across countries and organisations. I used the United States Environmental Protection Agency (USEPA) affordability ratio of 2.5% (Frankhauser and Tepic, 2007; Jepson, 2014). 72% of households were observed to spend below a 2.5% CAR within the studied sample.

Household physical resources

Physical resources present within household further help explain a household's capacity to water access and use. 90% of households within the study area had a piped connection within their premises. Although most households were observed to have no meter associated with their household standpipes. Another observation made was the existence of formal and informal connections of such standpipes. It was reported by ward committees and further validated during the survey through respondents' answers. 34% of household standpipes were reported to be informally set up by the households as piped access from the primary source of water. Besides the presence of standpipes, 33% of households also had a private borehole as an additional water source. Households reported that they had a borehole due to the financial strength and reduce water insecurity. 58% of the households had open pits without ventilation, which was the most common form of sanitation mechanism observed. 18% of the households had flush toilets, and the remaining households had open-pit sanitation wit ventilation.

Household water access and use

Water collected per capita per day was calculated through random recall method, whereby respondents answered based on their perceptions how much water has been collected per household member. An average of 33 litres per capita per day of water collection was observed with a high standard deviation across households. The storage capacity of each household was also measured through available storage mechanisms within households (i.e. buckets, drums, jojos). Highly variable storage was observed across datasets with an average storage capacity of 775 litres, within a range of 45 litres to 3500 litres. Further understanding of distance to the water source was made through the time required to collect water and the number of trips made to do so. The time required was calculated as respondents' recall for the time needed to collect water, including to and from a distance between household and various sources of water accessed in addition to queuing time at source. An average of 32 minutes of access to the source was observed within a varying dataset with the highest time taken to be 140 minutes. Similarly, the number of trips made to access such sources were also accounted for. Trip number to water source ranged between null (0) and 15 with an average of 2.4 trips per week. Mostly females from the household were observed to fetch water (36%). The task was shared amongst female along with children in 25% of households. Women and children were observed to carry water on their backs and through the use of wheelbarrows. The female primarily decided the amount of water to be collected without any consultation of the male members of the household. This trait was also similar across other household chores such as washing clothes, cleaning house, and how to ration household expenses.

Household social resources and adaptive capacity

Social resources available for households were measured as water network in terms of borrowing water. Respondents were asked as to how many households they could borrow water from when their household faced a water insecurity scenario. 75% of respondents reported such network to be less than or equal to 2 households in their neighbourhood. Additionally, respondents were asked about their quality of life (QOL) situation due to water insecurity, if any. In the present scope of the study, QOL was used as an over aching term to represent emotional, social and physical wellbeing of household members. Respondents were asked 'how often does water scarcity or insecurity in your household deteriorate your household's QOL?'. 33% of respondents reported 'often' and 'always' as a response, which meant those households faced a low QOL more than ten days in the last month due to household water insecurity. The adaptive capacity of households was understood through the household's involvement in the municipal meeting (i.e. stakeholder engagements, public participation, community meetings). 67% of households reported attending such meeting and complaint about their household water insecurity scenarios when need be. Both female and male households are allowed to attain such meetings, although a more significant percentage of male participants were reported. Respondents were also asked if they had thought of increasing their household storage capacity as a measure to prevent and or efficiently use water resources. 30% of respondents answered yes to such an adaptive capacity to water use. Also, 60% of households reported a willingness to pay for water services to the municipality to improve their household water situation.

Table 4 Household characteristics (categorical and continuous variables)

CHARACTERISTICS/ VARIABLE DEFINITION	**CATEGORIES**	**DISTRIBUTION N (%)**
RESPONDENT CHARACTERISTICS		
Household head sex	Female Male	86 (70) 37 (30)
Mean age in years (SD), (Min – Max)		48.76 (13.004) (26 – 79)
Mean Education level of respondent in years (SD), (Min – Max)		9.6 (3.65) (0 – 14)
Language spoken by respondent	Sepedi Sepedi and English	119 (97) 54 (44)
HOUSEHOLD DEMOGRAPHICS AND FINANCIAL CHARACTERISTICS		
Mean household size of adult equivalent (SD), (Min – Max)		5.11 (2.69) (1 – 17)
Mean average household income in Rands (SD), (Min – Max)		2412.93 (1.18) (0 – 10,275)
Who works in household	Female Male Both female and male No one works	12 (10) 34 (28) 12 (10) 61 (52)
Social grant status	Gets a social grant Does not get social grant	87 (71) 36 (29)
Water affordability	<2.5% of household income >2.5% of household income	89 (72) 34 (28)

HOUSEHOLD PHYSICAL RESOURCES		
Household has a piped connection to premises	Yes No	111 (90) 12 (10)
Status of piped connection to household premises	Informal connection Formal connection	42 (34) 81 (66)
Household has a private borehole	Yes No	28 (23) 93 (77)
Type of sanitation in household	Open pit Open pit with ventilation Flush toilet	71 (58) 26 (21) 22 (18)
HOUSEHOLD WATER ACESS AND USE		
Mean water collected per person per day in litres (SD), (Min – Max)		33.53 (16.88) (5 – 89)
Mean amount of water storage capacity within households in litres (SD), (Min – Max)		775.81 (809.25) (45 – 3500)
Mean time to access water source from household in minutes (SD), (Min – Max)		31.96 (34.85) (0 – 140)
Mean number of trips made by household members to fetch water in number of trips/ week (SD), (Min – Max)		2.4 (3.16) (0 – 15)
Who goes to collect water from household	Male Female Male and Female Female and Children	7 (8) 29 (36) 4 (5) 20 (25)
Mode of transport used to collect water	Walk Car Walk and car Delivered to household	72 (59) 2 (2) 2 (2) 22 (18)
OTHER WASH CHARACTERISTICS OF HOUSEHOLD		
Mean frequency of bathing per week (SD), (Min – Max)		2.1 (1 – 7)
Mean frequency of washing clothes per week (SD), (Min – Max)		3.1 (1 – 7)
Mean frequency of cleaning house per week (SD), (Min – Max)		1.8 (1 – 7)
HOUSEHOLD SOCIAL RESOURCES AND ADAPTIVE CAPACITY		
Deterioration in quality of life due to water insecurity/ scarcity in household	Never Rarely Sometimes Often Always	42 (34) 21 (17) 22 (18) 13 (11) 24 (20)

Complained to municipality, tank manager or other authority about water insecurity in household	Yes No	83 (67) 40 (33)
Thought of buying additional storage (i.e. buckets, drums, Jojos/ tanks)	Yes No	37 (30) 84 (70)
Willingness to pay for water services	Yes No	74 (60) 49 (40)
Social water network: Number of households you can borrow water from	<2 households >2 households	92 (75) 31 (25)

(Source: Author, 2019)

5.3.2 Developing perceived household water insecurity scale from ground-up

A total of 34 items were initially generated for carrying out the water insecurity survey. After conducting content and face validity with the 34 items on-site, a careful rephrasing of items was made. The final survey was carried out in the dry month of June in the study area (Figure 5). The total sample size of 123 households was considered sufficient for statistical analysis (Figure 1). All item responses were analysed for descriptive statistics. It was observed that responses 'often' and 'always' (referring to an event/ item occurring between 10 to 20 times and more than 20 times respectively in prior one month), were heavily skewed. Kurtosis and skewness values for these two options were observed to be above 1.96, and hence, the two response categories were merged into one. An affirmative response was counted for an item when respondents perceived it as occurring for more than 2 times/ days in the prior month. Before conducting statistical analysis on the 34 items, an item reduction was performed. As a first analysis for screening items, missing items were first removed from surveyed data. Items that had a more than 15% response rate of not applicable (NA) and refused to answer were first rejected from further analysis of data. Six (6) items were thus considered to be invalid. As a second step, I conducted an inter-item analysis. Exploratory factor analysis is predicated upon the assumption that data are continuous. Given the items used were of ordinal nature, a polychoric correlation was best fitted to carry out such analysis. Polychoric correlations allow for understanding item-item correlation and checks for variability amongst the items under analysis to formulate a scale. Following inter-item correlations, five (5) items were further removed due to very low correlations (<0.30) amongst themselves. Lastly, three (3) other items were additionally removed on behalf of high variance (>0.5) and low communalities (<0.3) as they created redundancy amongst items and lead to the formation of a negative matrix. Besides an inter-item correlation, an item total or polyserial correlation was also conducted to account for the relationship between individual items and the sum of scaled items chosen. All polyserial co-efficient obtained was greater than 0.3. Hence the remaining twenty-one (21) items were considered to carry out an exploratory factor analysis to determine factors for water insecurity scale. A frequency distribution for item responses along with their polychoric and polyserial correlations are shown as in Table 5. Scripts used for analysing inter-item and item-total correlations are shown in Appendix D.

Factor extraction was carried out by conducting a principal component analysis (PCA) with varimax rotation on the 20 items that were finalised after data screening and item reduction. Three criterions were used to understand the optimal number of factors to retain from the initial set. First, I examined the factor eigenvalues for those factors which had eigenvalues greater than 1.0 (Guttman, 1954; Kaiser, 1960). Eigenvalues of greater than 1.0 are preferred as it represents values higher than the average. Second, I performed a scree plot analysis by observing the base of the plot where the slope of decreasing eigenvalue approaches zero. Third, I checked for cross-loadings on individual factors. Items are assigned to factors if the corresponding item factor loading is greater than 0.40 (Cattell, 1966; Floyd and Wildaman, 1995). Based on the first criterion, PCA returned three (3) factors with greater than 1.0 eigenvalue, following which the scree plot was obtained and as shown in Figure 6. It can be noted that all three factors show significance above the observed scree. Factor loadings further suggest complete adherence of each item onto three separate factors/ domains. Each item had rotated component matrix values above 0.4 and was distinct (>0.2) from other observed factors. Hence no cross-loadings of factors were observed in the obtained analysis. Uniqueness scores for each item were observed, which portrays the unique variances of each variable. A large uniqueness value represents a more considerable variance and respectively lower relevance of the variable within the factor/ domain. No large uniqueness value was observed from factor analysis. Therefore, no further items were removed from the final set of 20 items.

The three factors combined showed a cumulative variance of 76% within the surveyed data. From the factor analysis, eight items loaded onto factor 1, with the largest variance of 63.25%. Four (4) and Five (5) items loaded on to factors 2 and 3 with variances of 7% and 6% respectively. The three obtained domains of perceived water insecurity were termed as per the cumulative description of each item within it.

Therefore, the three observed domains of water insecurity were:

- Perception of water access issues;
- Perception of unsafe water; and
- Perception of lost opportunity costs and social network due to water unavailability.

The three domains and the combined scale were checked for reliability by assessing for Cronbach's alpha. Internal consistencies for the combined household water insecurity (HWI) scale with 20 items was observed to be 0.96. Alpha values for the three remaining factors were observed to be 0.95, 0.88 and 0.78, respectively. Therefore, as all values of reliability were above an alpha coefficient of 0.70, the generated HWI scale can be deemed reliable. Items, rotated factor loadings and respective uniqueness values are as shown in Table 6.

Figure 5 Household water insecurity survey in the rural community of Ga-Mammadila (Source: Author, 2019)

Table 5 Frequency distribution of item response and polychoric/ polyserial correlations amongst isurveyed items (n=123) in rural and peri-urban communities of Hout catchment

ITEM	RESPONSE CATEGORIES				AFFIRMATIVE RESPONSE	ITEM ANALYSIS	
	Never	Rarely	Sometimes	Often/ Always		POLYCHORIC CORRELATION COEFFICIENTS	POLYSERIAL CORRELATION COEFFICIENTS
Unable to access/ use the primary source of water use for HH	26.0	12.2	20.3	15.4	60.2	0.43 – 0.77	.694
Felt worried and upset about HH water situation	52.8	18.7	22.0	3.3	26.0	0.47 – 0.86	843
HH drank less water than preferred	33.3	12.2	30.9	12.2	52.8	0.48 – 0.87	.862
Daily routines/ chores interrupted due to water situation in HH	52.0	16.3	25.2	4.1	30.1	0.45 – 0.83	.837
Not enough water for cooking desired meal for the HH	35.8	13.0	30.1	14.6	49.6	0.41 – 0.87	.848
Not enough water for cleaning the HH (including cleaning utensils)	58.5	10.6	22.0	6.5	29.3	0.42 – 0.91	.838
Not enough water for washing clothes for the HH	37.4	10.6	24.4	16.3	50.4	0.46 – 0.95	.846
Had to borrow water	31.7	11.4	20.3	24.4	55.3	0.45 – 0.91	.690
Had a dispute within household due to water situation	52.0	8.1	21.1	15.4	38.2		.445

Had to buy food due to water unavailability	52.0	7.3	18.7	6.5	28.5	0.44 – 0.81	.581
Complained to municipality/ ward office/ tank maintenance personnel	22.8	0.8	4.1	4.9	10.6	0.47 – 0.78	.562
Unsatisfied with water quality from primary source	62.6	5.7	13.8	3.3	30.1	0.52 – 0.83	.504
Had to drink water that was unsafe	49.6	22.0	17.9	4.9	26.8	0.45 – 0.92	.761
Had health problems	72.4	15.4	9.8	0.8	10.6	0.41 – 0.84	.747
HH had no useable or drinking water for a complete day	58.5	4.1	13.0	2.4	35.8	0.46 – 0.88	.757
Went to purchase water but there was no one to purchase water from	55.3	7.3	9.8	1.6	13.8	0.43 – 0.85	.524
Money problems to purchase water	52.8	13.8	8.9	3.3	22.8	0.44 – 0.89	.733
Had a dispute with neighbour/ other community people over sharing (borrowing/ loaning) water	54.5	4.1	18.7	2.4	21.1	0.44 – 0.86	.758
Children and young adults missed school/ university	48.8	13.0	26.8	4.9	33.3	0.41 – 0.87	.755
Got tired due to water collection	45.5	9.8	13.0	4.1	21.1	0.46 – 0.83	.499

***Never**: 0 times/ days, **Rarely**: 1 to 2 times/ days in prior month, **Sometimes**: 2 to 10 times/ days in prior month, **Often/ Always**: >10 times/ days in prior month, **Affirmative**: Greater than 2 times/ days in prior one month.* (Source: Author, 2019)

Table 6 Rotated factor loadings, uniqueness and domain identification of adapted twenty items from exploratory factor analysis

HOUSEHOLD WATER INSECURITY (HWI) SCALE ITEMS	ROTATED FACTOR LOADINGS			UNIQUENESS
	FACTOR 1	FACTOR 2	FACTOR 3	
DOMAIN 1: PERCEPTION OF WATER ACCESS ISSUES *(E = 12.4, V = 63%, A =0.95)*				
Unable to access/ use the primary source of water use for HH	**0.743**	0.111	0.330	0.3265
Felt worried and upset about HH water situation	**0.815**	0.367	0.244	0.1424
HH drank less water than preferred	**0.780**	0.318	0.374	0.1508
Daily routines/ chores interrupted due to water situation in HH	**0.869**	0.234	0.258	0.1232
Not enough water for cooking desired meal for the HH	**0.744**	0.429	0.311	0.1645
Not enough water for cleaning the HH (including cleaning utensils)	**0.828**	0.361	0.241	0.1265
Not enough water for washing clothes for the HH	**0.848**	0.351	0.251	0.0942
Had to borrow water	**0.634**	0.204	0.386	0.4081
Had a dispute within household due to water situation	**0.760**	0.267	0.323	0.2468
Had to buy food due to water unavailability	**0.739**	0.173	0.281	0.3455
Complained to municipality/ ward office/ tank maintenance personnel	**0.702**	0.477	0.122	0.2642
DOMAIN 2: PERCEPTION OF UNSAFE WATER *(E = 1.4, V = 7%, A =0.88)*				
Unsatisfied with water quality from primary source	0.141	**0.914**	0.119	0.1309
Had to drink water that was unsafe	0.401	**0.822**	0.240	0.1071
Had health problems	0.475	**0.619**	0.382	0.2456
HH had no useable or drinking water for a complete day	0.540	**0.683**	0.184	0.208
DOMAIN 3: PERCEPTION OF LOST OPPORTUNITY COSTS AND SOCIAL NETWORK DUE TO WATER UNAVAILABILITY *(E = 1.2, V = 6%, A =0.78)*				
Went to purchase water but there was no one to purchase water from	0.157	0.088	**0.911**	0.1373
Money problems to purchase water	0.478	0.067	**0.682**	0.3026
Had a dispute with neighbour/ other community people over sharing (borrowing/ loaning) water	0.219	0.423	**0.539**	0.4835
Children and young adults missed school/ university	0.336	0.285	**0.612**	0.4308
Got tired due to water collection	0.508	0.326	**0.605**	0.2692

E*: eigenvalue,* ***V****: Percentage of variance,* ***α****: Cronbach's alpha* (Source: Author, 2019)

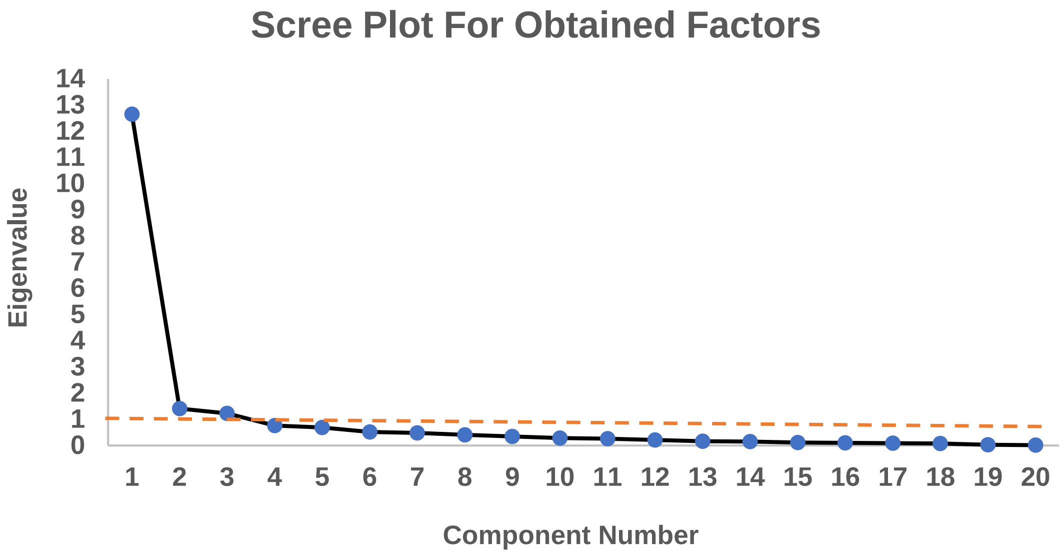

Figure 6 Scree plot analysis (Source: Author, 2019)

5.3.3 Determinants of household water insecurity

From the developed household water insecurity (HWI) scale, the mean responses of each household were calculated to score each item within the scale. Thus, the developed scale had a range of 1 (an item never occurring) to 4 (an item occurring often/ always), with a total score of 80 for each household. A higher mean score would indicate higher water insecurity and vice versa. Following the principal component analysis, the generated HWI scale and the domains obtained were used as dependent variables in multiple regression analysis to determine the factors influencing household water insecurity. Given there was more than one dependent and independent variable, I performed a multivariate analysis to understand the underlying factors to water insecurity. The multiple regression also performed simultaneously helps to validate the developed scale. The model results are as shown in Table 8. The scripts used for regression are as shown in Appendix D. For validation of the HWI scale, I performed two different types of construct validity tests. First, I tested for convergent validity of developed scale by correlating it to physical factors such as storage capacity of household, time to access water sources, number of trips made by each household to collect water, affordability of each household, presence of working piped connection, duration of water supply, quality of life for households, coping strategy and social resources available to households. Second, I checked for discriminant validity against developed scale and quantity of water used in the household (in litres per capita per day). Various other researchers have found a significant negative relationship, and hence, this independent variable was used for discriminant validity analysis (Jepson *et al.*, 2017).

The developed models were found to be appropriate as it fit the survey data very well. The models had significantly high F value, significant p values and adjusted R2 values suggesting a relevant relationship between the predictor and response variables. Heteroskedasticity and multicollinearity of developed models were also checked for by assessing residual variances and variance inflation factor (VIF). Average variance inflation of the models was 1.59, and the highest VIF of 1.63 was observed across the four models. Additionally, Ramsey's regression specification error test (RESET) was performed to check further model specifications. The RESET test returned significant F and P values and confirmed for no omitted variables within the models. Hence it can be established that the regression models generated coefficients which are unbiased, efficient and consistent for further analysis. Table 7 shows the regression model specifications.

The results indicate that affordability of water has a significant negative correlation with the overall household water insecurity scale. The households which can pay for water as more than 2.5% of their daily income are less water insecure and vice versa. Such households can afford to purchase water from various other sources besides the piped connection to their household premises. It was observed that most households in the study area tend to save money and adapt to the minimum amount of water usage on a need basis. Based on item 14 of the survey, 32% of the households buy water to meet their household needs and avoid water insecurity. Also, through item 17 of the household survey, a reported 24% of households confirmed they lack adequate money to buy water even if they wanted to. Households in the study area primarily buy water through private tanker suppliers who deliver it to the households at a varying cost of 300 to 550 Rands for filling a 2500 litres JOJO (tank). Other sources of buying water were bottled water and drums from private shops. Water affordability also had a significant negative correlation with two domains of the HWI scale: perceptions of unsafe water and perception of lost opportunity and social network due to water unavailability. This proves that poor water access to households is the prime reason for households to look for alternative water sources. Amongst such households, those that are economically stronger can afford to buy water while others look for free communal sources at a distance from the household as an alternative. Correlation of water affordability with lost opportunities and depriving social network highlights the presence of uneven resource within the study area. 18% household reported water being delivered to them through private tankers, and 2% proclaimed to use their personal vehicles for buying water when the need arises. Such households which buy water through privately delivered water trucks reported delayed delivery times leading to episodes of water insecurity within the household. Even after adapting to scarce water resource with appropriate planning and management, these households still have to face a water insecure condition by the end of the month. This leads to a interrupted personal life and creates further tensions amongst the neighbourhood where they are obliged to fetch water from other sources and or borrow water respectively. Personal wellbeing thus reduces due to adults missing work and children their education. Households with scant financial resources and living off government grants reported they had never thought of buying water as the need to spend money on the water came as a secondary choice and they preferred to depend on the standpipe water or other communal or free sources of water.

Table 7 Regression model specifications

MODEL NAME	ADJUSTED R^2 VALUE	MEAN VIF	F VALUE	P VALUE	RAMSEY'S RETEST VALUE
Model 1: With HWI scale	0.553	1.59	10.056	.000	F = 1.3 P = 0.27
Model 2: With Domain 1 (*Perception of water access issues*)	0.616	1.59	12.753	.000	F = 1.93 P = 0.13
Model 3: With Domain 2 (*Perception of unsafe water*)	0.229	1.59	3.175	.000	F = 1.61 P = 0.20
Model 4: With Domain 3 (*Perception of lost opportunity costs and social network due to water unavailability*)	0.347	1.59	4.892	.000	F = 1.6 P = 0.20

(Source: Author, 2019)

Table 8 Multivariate regression of household water insecurity and its domains across categorical and continuous variables

VARIABLE	MODEL 1		MODEL 2		MODEL 3		MODEL 4	
	β	SE	β	SE	β	SE	β	SE
Gender (Male =1, Female =0)	-0.210	0.152	-0.137	0.160	-0.172	0.179	**-0.402**[a]	0.226
Age (in years)	-0.001	0.005	-0.006	0.005	-0.003	0.006	0.011	0.007
Education level (0 to 7 years =1, 7 to 14 years =0)	-0.010	0.018	-0.006	0.019	-0.009	0.022	**-0.055**[b]	0.027
Household size (adult equivalent in number of members living at present within household)	0.014	0.028	**0.048** [a]	0.029	-0.043	0.033	-0.012	0.042
Social grant (Yes =1, No = 0)	-0.211	0.155	-0.183	0.162	**-0.455**[c]	0.182	-0.059	0.230
Quantity of water collected (in litres per capita per day)	-0.007	0.005	-0.008	0.005	**-0.013**[b]	0.006	0.002	0.008

Storage capacity of water within household (in litres)	-4.185E-05	9.723E-05	8.957E-06	0.000	-3.979E-05	0.000	0.000	0.000
Water affordability (<2.5% of income =1, >2.5% of income = 0)	**-0.326**[b]	0.153	**-0.409**[c]	0.160	0.076	0.180	**-0.422**[a]	0.227
Working piped connection within household premises (Yes = 1, No = 0)	**0.305**[a]	0.162	0.239	0.171	**-0.387**[b]	0.192	0.263	0.241
Duration of water supply to piped connection within household (in hours/ week)	**-0.005**[a]	0.002	-0.003	0.003	-0.004	0.003	**-0.007**[b]	0.004
Time taken to fetch water from alternative sources (in minutes)	**0.005**[a]	0.003	**0.007**[c]	0.003	**0.007**[b]	0.003	-0.001	0.004
Number of trips made by household members to fetch water (in number/ week)	**0.059**[b]	0.030	0.049	0.032	0.035	0.035	**0.093**[b]	0.045
Effect of water situation on quality of life of household members (Never = 0, Always = 5)	**0.151**[b]	0.071	**0.249**[d]	0.075	-0.082	0.084	0.113	0.106
Coping to water insecurity by buying additional storage (Yes =1, No = 0)	**0.311**[b]	0.145	**0.309**[b]	0.153	0.221	0.172	0.341	0.216
Social network of borrowing water from neighbours (>2 households = 1, <2 households = 0)	0.200	0.171	0.273	0.180	0.037	0.202	0.190	0.254
Access to municipality meetings and other decision-making forums (Yes = 1, No = 0)	-0.102	0.150	-0.067	0.157	0.070	0.177	-0.306	0.223
Intercept	2.539	0.529	2.554	0.555	9.757	0.624	1.881	0.786
Adjusted R^2	**0.553**[d]		**0.616**[d]		**0.229**[d]		**0.347**[c]	

β: *Adjusted co-efficient*, ***SE***: *Standard Error*, ***Ref***: *Reference value*, [a]*p-value<0.1*, [b]*p-value<0.05*, [c]*p-value<0.01*, [d]*p-vale<0.001*(Source: Author, 2019)

Presence of a working piped connection within household premises also had a significant positive relationship with water insecurity. A total of 90% of the households had a working piped connection within their household premises. Although such households scored less on the water insecurity scale, there was a reasonably high variance amongst the score. Households reported that presence of a piped water connection was in no way securing their household water situation for various reasons. Presence of formal and informal connections, vandalism of piped resources, elevation from the source tank and water pressure issues are amongst the primary reasons for a failed pipeline access. A total of 34% of households within the survey reported having informal standpipe connection within their household without the information of the local municipality. As most of the surveyed communities depend on the pre-apartheid water infrastructure, households pointed out the failure of maintenance of such infrastructure. For example, a particular surveyed community within the study area reported to depend on two boreholes which pump water into two overhead tanks, and it is then supplied across the community. Amongst the boreholes, one has been non-functional for over ten years, and the other functional borehole performed poorly as per household perceptions. Water pressure and in turn distance of the household from the community overhead tanks hence also define the duration of water supply to the household standpipes. These in addition to vandalism of boreholes and pumps further reduce household water security incrementally. Working piped connection also had a significant negative relationship with sub-domain of the scale related to the perception of unsafe water. This correlation highlights the presence of perceived poor quality of water as obtained from the household standpipes. Households reported of pungent smell, odour, turbidity (reported as muddy and brown water) in their standpipes from time to time. Households in the Dendron community reported about highly saline water at all times from standpipes. Duration of water supply to the standpipes was also found to have a significant negative relationship with water insecurity. Households which were geographically suited as described previously mostly had access to a fairly long duration of water supply as compared to Regional Development Program (RDP) houses which were farther away towards the end of the community. According to households, blockage of pipelines or faulty pipelines further reduced water supply duration. While some communities have fixed days and times for water supply from the main tank, most households reported of infrequent supply and no prior notice. 45% of surveyed households reported to have a water supply for 0 to 30 hours spread across the week, with a varying flow rate across the water supply days. Water supply duration also showed a significant negative correlation to sub-domain related to the perception of lost opportunity and social network. This further establishes the link that less duration of water supply and accessibility leads to disruption of personal wellbeing, social relationship disruption and lack of educational and finance opportune for the household members.

The study hence found that in terms of water access, the presence of a working standpipe did not guarantee water security at a household level. Most households depend on additional sources of water irrespective of a formal or informal working piped supply. A large number of households reported and were observed to depend on communal standpipes from within their community or communities nearby. Therefore, two other physical variables of time required to access water sources and the number of trips made per week to collect water were analysed with developed perceived water insecurity scale. Time and number of trips were used a proxy of distance to water sources in the present study. As per *priori* expectations, both variables had a positive correlation to water insecurity. Thus, more the time required and larger the number of trips a household member makes to access water, the water insecurity increases. The time required to fetch water also had a significant positive correlation with subdomains of the water insecurity scale dealing with water access and poor water quality. This portrayed the need to fetch water from near or far sources for appropriate water as perceived by the household members. Additionally, the number of trips made to fetch water had a positive statistical significance with subdomain related to lost opportunities. From the survey analysis and discussions with households, it was understood that mostly female and children had the duty to fetch water within the household. 59% of households reported walking as the only mode to fetch water. Use of wheelbarrows was observed to be most prominent across the study area, along with few women carrying water on their heads as the second most used method. Females reported the negative toll of water fetching on their daily health and spoke about increasing tiredness and lack of social life. The use of donkey carts to fetch water from various communal sources and selling such water was also observed to be a common trait across the surveyed communities.

Quality of life (QOL), which was measured as a subjective statement on depletion of household members' emotional, social and physical wellbeing was used as a variable to correlate water insecurity to water distress. The water insecurity scale had inbuilt items on the emotional wellbeing of the household due to water unavailability or insecurity. As per *priori* expectations, QOL also showed a positive correlation to water insecurity as compared to households who never faced a decreased QOL, households which faced such decrease more than ten times in the last month were more insecure. Hence this correlation further highlights the degree of emotional distress that is caused due to water insecurity. QOL was also found to be statistically significant with sub-domain of poor water access. Thereby further highlighting the underlined water distress perceptions as observed from qualitative discussions with the household heads. Lack of personal wellbeing and lack of enough water for household chores leads to worry and upset, thus affecting QOL of households. During the survey, households were also asked about various coping mechanism they adhere to in order to reduce water insecurity. The most spoken about coping mechanism was the thought of buying additional storage for the household. Household water insecurity further showed a positive correlation with coping to water insecurity through obtaining additional storage. Households which had bought additional storage in the past few months showed reduced water insecurity as compared to households who have not done so. Coping by buying additional storage also was positively correlated with sub-domain related to poor water access, highlighting households' motivation to save money and adapt to uncertainty. This correlation portrays the importance of storage mechanisms in a semi-arid climate and in particular to increase water security in light of challenging water access issues.

To analyse for discriminant validity, the overall water insecurity scale was correlated with water quantity collected and consumed by household members in litres per capita per day. Although negatively correlated, no statistical significance was observed in the overall water insecurity scale. This may be due to the different water quantities used across the various communities. While some may use more water for bathing and cleaning house, others adapt with minimum water resource made available depending on time. Quantity of water had a statistically significant correlation to the subdomain of the water insecurity scale about the perception of unsafe water. This correlation highlights the relationship between quality and quantity of water as perceived by the households. As reported by various households that when a water source is of poor quality, they reduce their water usage from such sources (which is mostly their household standpipes). Reduced quantities as compared to households who have better quality water leads to reduced water insecurity for the former type of households. The storage capacity of households was negatively correlated to water insecurity though not statistically significant. This could be possible due to households having their own private boreholes which have a continuous supply of water and does not require large storage mechanisms. The negative correlation highlights that a household with better storage capacity

is more water-secure and vice versa. Socio-demographic factors related to gender and education showed statistical correlations with sub-domain of lost opportunities and social network. A female-headed household was statistically less water insecure as compared to male-headed households in terms of social interactions and personal wellbeing as measured through the third domain of the scale. A higher education status showed improved social and living standards. Whereby, members of the household who have had a college degree had better jobs and more financial resources to improve their household condition and thereby household water security. Social grant and Household size also showed a significant correlation to water insecurity sub-domains. Whereby larger the household size, greater was the water insecurity for the household. Social grant showed a negative correlation to water insecurity. The negative correlation highlights social grant and monetary help does not significantly affect water security for a household. The low-income households who mostly receive such grants were not able to meet their water security based solely on the minimum social grants they receive.
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5.3.4 Salience of water as determinant of food insecurity

Water plays a vital role in ensuring household food security. The same was observed through qualitative discussions and item analysis while pursuing the cross-sectional survey. Trade-offs between water and food is a common occurrence across all the surveyed communities. Access to water resources in addition to water affordability, was qualitatively understood to be the primary underlying factors to household food security. Households reported a longer duration to fetch water sometimes makes them skip cooking meals due to tiredness. Households were observed and reported to change their food pattern as per household’s water availability. In low-income households, in times of water scarcity, household head reported rather to buy food as compared to water to survive through the month. Change in food patterns was thus observed to be the most common manifestation of water unavailability. 35% of the respondents reported about buying food in times of water unavailability as compared to purchasing water. This was a significant trait, as observed across the peri-urban communities. Rural households, on the other hand, coped to water insecure situations by change or reduction of food consumption. 30% of the survey respondents reported about changing their food pattern from pap (wheat-based meal, which is a prevalent diet in RSA) to bread. 18% of the surveyed household heads also highlighted that they had had at least one day in the past month where their household had no useable water at all. The scenario was different amongst economically stronger households or households with boreholes, which had a continuous supply of water and hence better food consumption and health. Farming households reported to make use of their backyard farms whenever possible, but lack of water makes them unsuitable for growing cash crops even for household consumption. Majority of smallholder subsistence farmers were observed to grow maize, and hence, it is the primary food security crop for most families. Determinants that affect a household’s water insecurity were perceived to affect a household’s food insecurity similarly. Therefore, to draw correlations amongst water and food insecurity, further analysis was done as presented below.

5.3.5 Relationship between water and food insecurity

Before assessing further correlations between water and food insecurity, I first drew up some descriptive analysis to bring forward the underlying relationship. The household water insecurity scale developed had continuous variables (calculated as mean scores) for every surveyed household. The scale was further used to objectively classify households into different types of water (in)security. Various socio-economic studies have used the 40th percentile as a cut-off to the poverty line (Vyaas and Kumaranayake, 2006; Achia *et al*., 2010; Sinyolo *et al.*, 2014). Based on this understanding, the 40th and 80th percentiles of the household water insecurity scale were classified as highly water insecure and marginally water insecure. While those above the 80th percentile fell into water-secure conditions. Following this classification, Figure 7 describes the number of households that fall into each category as per the household water insecurity (HWI) scale and its three domains. An average of 49% and 39% fell into the highly water insecure and marginally water insecure households across all domains of the HWI scale. Households which were water-secure perceived unsafe water as their biggest issue amongst the three factors that were determined as per *posteriori* analysis. The change across the scales reflect the behaviour, perceptions and wellbeing that are affected across the study area. All three domains of HWI scale are highest amongst the highly water insecure households. While marginally water insecure households perceive water access issues as one of their major hindrances to water insecurity.
Further based on mean scores of both HWI and HFIAS scales, correlations were drawn between water and food insecurity for the surveyed households. As per *priori* expectations, it was observed that households which are water insecure are more strongly food insecure as compared to households which are water secure. The margin of difference between water and food insecurity was observed to be fairly lesser in marginally water insecure groups as compared to highly water insecure households. This further strengthens the trade-offs that low-income household makes between water and food. The relationship via mean scores between HWI and HFIAS scales are as shown in Figure 8.

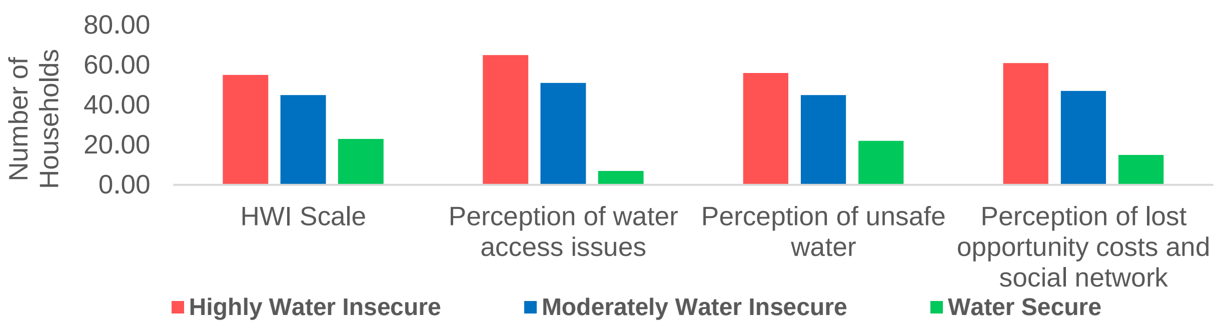

Figure 7 Water insecurity domains across households within the study area (Source: Author, 2019)

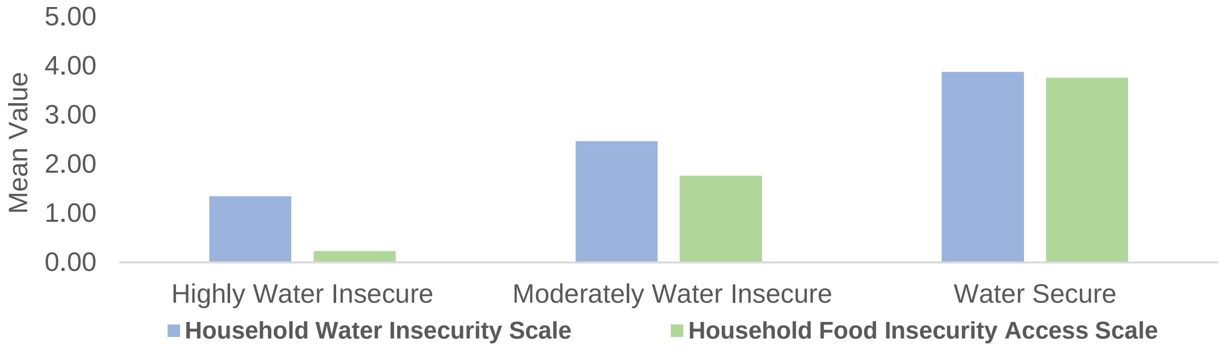

Figure 8 Mean scores of HWI and HFIAS scales (Source: Author, 2019)

Household food insecurity was measured by using USAID's 'Household Food Insecurity Access' (HFIAS) scale (Bilinsky and Coates, 2007). Through item analysis of the HFIAS scale, 67% of the households reported to eat a limited variety of food, and 57% responded affirmatively to not being able to eat the kind of food they preferred. The descriptive statistics, as obtained from HFIAS, is as presented in Table 9. The items of the HFIAS scale were checked for item total and item-item correlation, and none of them had any significant low values which ought to be removed before analysis. The survey obtained HFIAS scale was checked for reliability and had a Cronbach's alpha value of 0.95 and hence was acceptable. Further, the scale was calculated as per USAID HFIAS guidelines, whereby if a household said no to the occurrence of an item, the score for that household was not calculated. To further enhance descriptive analysis, regression results showed a strong significant correlation between water and food insecurity ($\beta = 0.38$, $p = .000$, one-sided test).

Two of the obtained domains of household water insecurity also showed significant correlations to food security. Perception of water access issues was positively correlated with food insecurity ($\beta = 0.716$, $p = .000$, one-sided test). Therefore, longer the water access and water acquiring process, higher is the household's food insecurity. Also, perception of unsafe water showed a significant negative correlation to food insecurity ($\beta = -0.166$, $p = .002$, one-sided test). This correlation highlights that households perceive water quality as a threat but due to lesser available and or reduced quantity, water quality is not given priority to. Survey respondents had voiced that they use water from safe and unsafe sources across their household and domestic purposes equally. Treating water was a rare practice, even in economically stronger households. Perception of lost opportunities and social cost showed a negative correlation with food insecurity, although it was not statistically significant. The negative correlation shows that loss of social relationships and opportunities for water collection comes at the cost of ensuring food security. The households who has better social water network to borrow, share and lend water amongst themselves without hindrance hence can avoid water and food scare situations and vice versa.

Table 9 Descriptive statistics of HFIAS scale

SCALE ITEM	RESPONSE CATEGORIES			AFFIRMATIVE RESPONSE
	RARELY	SOMETIMES	OFTEN	
Worry household would not have enough food	34.4	22.2	17.8	40.0
You or any Household member were not able to eat preferred kind of food because of lack of resources	21.1	32.2	24.4	56.7
You or any Household member have to eat limited variety of food because of lack of resources	12.2	32.2	34.4	66.7
You or any Household member have to eat some food that you did not want to eat because of lack of resources	20.0	36.7	12.2	48.9
You or any Household member have to eat a smaller meal size	23.3	30.0	18.9	48.9
You or any Household member have to had to eat fewer meals a day	23.3	30.0	18.9	48.9
had no food of any kind in your household because of lack of resources	31.1	22.2	13.3	35.6
You or any Household member went to sleep at night hungry because there was not enough food	18.9	14.4	1.1	15.6
You or any Household member go a whole day and night without eating because there was not enough food	14.4	12.2	1.1	13.3

(Source: Author, 2019)

To further breakdown the correlations and analyse for which determinants of water insecurity affect food insecurity, I performed a stepwise multiple regression with a selected set of predictor variables. Demographic variables of gender, household size, grant and education were kept as control variables in these models. The stepwise analysis thus brought forward the variables that best explain the association between household water and food insecurity. Three models were generated from the stepwise multivariate analysis. All three models showed significant adjusted R2 values (0.85 to 0.86), which recognizes that a stronger variance of food insecurity was identified. The model statistics are as shown in Table 10. Scripts used for running the statistical analysis are shown in Appendix D. When controlled for demographic variables, the overall household water insecurity scale showed a strong positive correlation to food insecurity across all three models. Although, with the addition of predictor variables, a slight decrease was observed in the HWI scale (0.416 to 0.324, $p<0.001$ for all models). This explains a strong overall association between household water and food insecurity whereby water insecure households tend to be more food insecure and vice versa. Domain 1 of the HWI scale relating to the perception of water access issues also showed a strong positive correlation, which was statistically significant. A similar trait of a slight decrease in correlation was observed for domain 1 on the addition of more predictor variables (0.577 to 0.543, $p<0.001$ for all models). This highlights that water access is the primary reason leading to household food insecurity as compared to the other two domains, which showed correlations but were not statistically significant. Statistical results further indicated that female headed households were more food insecure as compared to male headed households. It was observed that male headed households had more income as compared to the average income of female-headed households, and this could signify the higher food security for the former type. The stepwise multivariate model also showed a small, significant association with household size; indicating larger the household capacity, higher is the food insecurity. Such trait was also observed through qualitative discussions, whereby respondents reported about food allocation and household members skipping meals altogether to sustain the children and other members of the household. Social grant also showed a strong and positive correlation to food insecurity, wherein households which receive some sort of government monetary support are more food secure as compared to those who don't. As observed before, social grants had a negative correlation with water insecurity. The receival of social grants are more pronounced across lower income households and such households, prefer to spend money on buying food when faced with water insecurity as compared to buying more abundant water storage or water in general. Thus, the correlation of social grants across food and water insecurity, further establishes how low-income households allocate their limited funds and highlights the water and food the trade-offs made in the household. The storage capacity of households showed a small but significant negative relationship to food insecurity. As explained previously, households with larger storage capacities would have more water resource allocation and would be more adapt to uncertainties. Hence such households would have lesser food insecurity as compared to households with lower storage mechanisms. As per *priori* expectations, model 2 also portrayed time taken to fetch water having a small significant positive correlation with food insecurity. Generally, it was observed that women are solely responsible for household chores (including cooking) and also fetching water. Longer time required in accessing and acquiring water for households makes them tired and or provides them with minimum resources and time to prepare food. On adding social and emotional distress related predictors on to model 3, a strong positive correlation was observed between the quality of life and food insecurity. This highlight emotional distress caused across households in both domains of water and food status and further brings out the relationship between them. Social network to borrow water from neighbours also showed a positive correlation to food insecurity. Households, which can borrow water when in need are thus able to meet their food demands as compared to households who fail to borrow. Therefore, beyond water access, various social, economic, emotional and adaptive capacities of households define their respective water and food scenarios.

Table 10 Stepwise multiple regression of HWI scale and its domains on HFIAS scale, controlling for predictor variables

VARIABLE	MODEL 1		MODEL 2		MODEL 3	
	β	SE	β	SE	β	SE
HWI Scale	.416 [d]	.607	.362 [d]	.638	.324 [d]	.746
Domain 1: Perception of water access issues	.577 [d]	.486	.565 [d]	.478	.543 [d]	.495
Domain 2: Perception of unsafe water	-.064	.391	-.075	.383	-.056	.398
Domain 3: Perception of lost opportunity costs and social networks	-.030	.313	-.010	.316	-.002	.316
Gender (Male = 1, Female = 0)	.078 [b]	.633	.094 [b]	.627	.099 [c]	.622
Household size (adult equivalent)	.071 [a]	.111	.080 [b]	.109	.077 [b]	.109
Social grant (Yes = 1, No = 0)	.176 [d]	.639	.163 [d]	.639	.158 [d]	.652

Education (0 to 7 years =1, 7 to 14 years =0)	.036	.078	.032	.076	.025	.077
Storage capacity of water within household (in litres)			-.065 ^{a}	.000	-.070 ^{a}	.000
Time taken to fetch water from alternative sources (in minutes)			.072 ^{a}	.011	.042	.011
Effect of water situation on quality of life of household members (Never = 0, Always = 5)					.104 ^{a}	.347
Social network of borrowing water from neighbours (>2 households = 1, <2 households = 0)					.055 ^{a}	.697
Intercept	-9.245 ^{c}	3.352	-7.541 ^{b}	3.344	-7.966 ^{b}	3.322
Adjusted R^2	0.856		0.863		0.866	

***β**: Adjusted co-efficient, **SE**: Standard Error, **Ref**: Reference value, ^{a}p-value<0.1, ^{b}p-value<0.05, ^{c}p-value<0.01, ^{d}p-vale<0.001* (Source: Author, 2019)

5.3.6 Qualitative findings from cross sectional survey

Qualitative findings portray the ethnographic observations from transect walks and interpretive analysis of discussions with the households while performing the cross-sectional survey. I further classified such findings into broader categories of socio-demography, physical resources available to the households, water access and use, social resources and networks of the households and quality of water available for households.

Socio-demographically, households in the rural and peri urban communities of the Hout catchment had an average household size of approximately 4 to 5 adult equivalents. Females were observed to be the likely household head, having the best knowledge about household situations and livelihoods. Females reported to ration between household finances and water scenarios with or without the acknowledgement of their male counterparts. Household chores and decision making about where to collect water from and how much to collect were primarily a woman's responsibility within the household. Education level of households varied widely from no education to graduate level education and skills across the study area. Household size was observed to scantly affect household education levels. In general, most households were observed to have some basic education and majority spoke English besides their local languages. Better education and willingness to have a better livelihood was observed to be a strong motivation amongst surveyed households. A female survey respondent spoke of her willingness as: "*I have started to do volunteering jobs to earn some money to get water for my household*". Additionally, households with better education level were more aware of their water scenarios in terms of quality of water and waste water management practices. A survey respondent who was a graduate and has a private job observed poor water quality referring to local municipality obligations as:
"*People in my community are unaware where waste water from our households go to. Although all houses in this community may have a link to waste water system through pipelines from flush toilets, there are visual signs of leakage across the community and on the way to the main*

treatment plant along the roads. When complaints are made to local municipalities, they are generally very irresponsive on such situations" (Survey Interview, Dendron, June 2019).

Household incomes were highly variable across the different communities. Most communities had a visual geographical or spatial diversification with newly adopted RDP households to one side of the community which were mostly made of tin or bricks. More developed or older households were located towards the centre or near to community water supply sources. The right to land ownership is primarily with the village chief (Ndona) of the community. Traditional government structures are perceived to be a strong establishment of local governance within all the communities except for the peri-urban settlements. Such settlements functioned more closely under the supervision of the local municipalities directly and even housed a regional municipality office within the community. Depending on household structures and number of years of residency in a particular community was observed to play a prime role in understanding a household's water situation. Household incomes were reported to come from various sources across the study area. Income sources varied substantially across the communities from personal job incomes, receiving pensions, receiving social grants from the government or receiving money from extended family members who stayed in the larger cities and had a better job. Mostly, survey respondents who are more aware of their socio-economic situation were observed to focus more on their children's education and upbringing so as to provide them with a better life. Households prioritise their expense and hence trade-offs occur between various expenditures for daily livelihood and wellbeing and in particular between ensuring food and water security. Some respondents who survive primarily on social grants reported to keep water expenses at large, preferring to change food patterns and even skip and reduce meal sizes to live through the month when there is a water scarce situation. Households were observed to adapt to minimum water availability and live within a waterscape dominated by poor water access, quantity and quality. Survey respondents with a relatively larger household income as compared to former households reported to make better monthly budget decisions and cope with water situation in terms of planning to increase storage and or water availability. Such households also had a better ratio of both male and female working to increase household incomes. Water affordability thus was better for these households, whereby their income levels were higher and they could outrightly spend more finance on alternative sources of buying or fetching water through private deliveries when such need arises. Households with a stronger income per capita also could afford to invest in private water sources such as drilling a borehole within household premises and or buying Jojos (2500 litres tanks). Households with lower income levels reported more to save money and paying for water or having private boreholes as a "*privilege they cannot afford to have*".

Physical resources available to households can be of various categories. The most important physical resource that may increase a households' water security is the presence of a working piped connection within household premises. Additionally, storage mechanisms within households also may increase water situation and wellbeing. Presence of such physical resources are determined by an array of support structures that are both up to the households and also a duty of the local government or municipality. As per the South African government access to private standpipes within 200 meters of a household is a duty of the local municipalities under the free basic water act. Although 78% of households were observed to have a formal or informal standpipe within household premises water insecurity was still high amongst such households. The communities primarily depend on a pre-apartheid water infrastructure and delivery system. Whereby, communities depend on 2 to 4 boreholes which pump water into overhead or on the ground level tanks. These tanks are either made of cement or stainless-steel make. The boreholes are guarded with a lock and key system and has a tank operator from amongst the community who has the responsibility of operating the pump house on given days and notify the community about water supply. Water is pumped for a given duration and stored into the said tanks and supplied across the community on pre mentioned days through a piped system. Most communities reported to have a central pipeline system with branches and sub-branches diversifying from the central pipeline into respective standpipes of the households. A formal one-time connection fee of 250 Rands is taken by the municipality to set up a standpipe within household premises. The cost of additional pipeline to access the central pipeline is the responsibility of the household, which is approximately another 300 to 450 Rands. Therefore, the substantial expense of ensuring a formal connection is a costly and lengthy procedure for a significant number of households with lower income levels.

Figure 9 Informal connection within households (Source: Author, 2019)

A reported 34% of surveyed households had informal standpipes (Figure 9). Such informal connections exist either where the household invests and sets up its own piped network without the information of the local municipality at a cheaper cost and or use a smaller diameter PVC make pipe and a hose pipe directly into premises without a standpipe setup. Households without any formal or informal standpipe reported that they lacked sufficient money to ensure either access. A couple of such households even had no electricity access and depended on their water sources from households in surveyed area within the Polokwane municipality had standpipes without a meter. When asked about if households need to pay for water services, a general trend of water as a free basic right was significantly observed. Three communities within the Polokwane municipality of Hout catchment are surface water dependent from the Hout dam that supplies water into the community tanks and thereby from the tanks to the households. These three communities were the most reluctant about the usage of water meters. A survey respondent from one such community Ga-Mammadila described his emotions as:

"*We paid enough to help build the dam, water should now be free! But I would not mind to pay a bit more to get more water for myself. It would help in my farming and agricultural growth*" (Survey Interview, Ga-Mammadila, June2019).

The community of Dendron within MoleMole municipality was observed to have a metered standpipe access across every household. Although when surveyed it was understood that a vast majority of the population has been on strike with their municipality as the standpipes are non-functional with no water supply for months and in some cases even years. A section of the Dendron peri-urban community gets water supply in their standpipes due to a better elevation and some households with more income could purchase a pressure pump to extract water from the central pipeline. A minority of these households reported to pay their water bills which averaged to 520 Rands. Although most households with pressure pumps reported of non-payment as they have invested in a pump themselves to ensure their water supply and "*are not liable to the municipality*". Therefore, it was observed that willingness to pay for water services varied vastly depending on awareness, livelihoods, personal perceptions and emotions and an understanding and knowledge of what is free and what may not be so. A male survey respondent from a groundwater dependent community, Matikering of Polokwane municipality, who faces challenges due to extremely low supply and regular water cut-offs in their formally established household standpipe reported:

"*I would prefer a pre-paid working metered connection in my house like we have for electricity. It's okay. I will then pay for water according to meter and money I have. At present when I order water tankers it sometimes takes more time to be delivered. Our lives are more difficult when we run out of money and they (tanker water) do not come on time. Meters will be much better.*" (Survey Interview, Matikering, June 2019).

Besides a piped connection household in the study area also inhabit different other physical sources to increase their household water security. The use of storage mechanisms such as 250 litres drums was observed to be the most common across all communities. As described previously, household income plays a significant role in ensuring purchase and maintenance of such storages. Households with moderate to high income were observed to own 2500 litre capacity Jojos or bigger tanks. Availability of such physical resources increase a household's adaptive capacity by coping for uncertainties. In households with more financial strength, besides acquiring larger storage, a trait of securing household water situation through drilling of personal boreholes were observed across all communities.

Such households were observed to be of more valued social status within the communities and often shared water with neighbours when asked for, at a cost or for free. However, for low income households and for households where piped water supply is scant and largely infrequent, they either do not think of purchasing larger storage or lack the money and will to do so. Such households mostly depend on communal water sources from near or far from their household, whichever is available. Across all communities a trait of initial dependence on household standpipe was observed if and when working. Households which do not have sufficient money to purchase multiple drums, at the least has one drum (250 litres) and several buckets (30 litres) where they store water. Although the household members try to ration their water needs, it takes a severe toll on their household chores. 49.6% households reported to drink less water than preferred. 29.3% of the households reported a disruption in daily chores. 50.4% of household said they were not able to cook desired meals, 55.4% of surveyed households reported of not enough water to clean households and 55.3% of households reported not enough water to wash clothes. When out of water, household members and as previously described the women and children of the household goes to fetch water from various sources (Figure 10). Across the groundwater dependent communities, none of the household reported to access ponded water or unsafe water.

Figure 10 Female household heads fetching water (left), use of donkey carts to deliver water from communal taps (right)

In the community of Dendron, where the newly developed RDP houses are towards one portion and the other established houses on the other a stark differentiation of water access was observed although all houses had a metered water connection. In the RDP region, the municipality has set up Jojos (2500 litre tanks) across every 4 lanes which is filled bi-monthly through a municipal tank supply. Although such system is in place, longer queues at the community tanks, uninformed supply days and times and quarrel and fights to access water on first come first serve basis leads to a disrupted social life amongst community members. Similar traits were observed across other communities which were completely dependent on community sources. Matikereng, another such community has no JOJOs but community standpipe access. Two (2) standpipe on every alternate lane were present with a couple of standpipes reportedly non-functional. Households talked and described similar problems as in Dendron, whereby communal relationships are regularly disrupted leading to an unsafe situation. Across the surface water communities, given their vicinity to the river bed and Hout dam, households reported to access water from ponded pools on the river bed when there is a water scarce situation. Such sources are commonly shared for livestock and cattle grazing.

Although water access to these surface water dependent communities are from the dam, they face regular cut-offs and delayed deliveries. Households reported in times of extreme situations, the dam supplies water tankers which help supply water across the community. Mabokelele community which is supplied by the Hout dam, has pipelined system directly from the dam into respective standpipes of the household. Even with a direct supply system from the dam, households reported that standpipes were not operational since months and or has "*extremely low flow*". Visual observations from transect walks proved their point of view, whereby houses have removed their standpipes and pulled out the pipe, thereby collecting/ ponding water into a dug hole/ pit over time.

Figure 11 Municipality supplied water tanker (Source: Author, 2019)

Municipality supplied water tankers (Figure 11) were reported to deliver water three times a month. The tanker supply was reported to be highly infrequent, with sometimes the tanker arriving three consecutive days and other times 3 days spread across the month. Community ward members reported of tanker supply being stopped for a month or extended periods of delayed deliveries. Unlike in Dendron, the tanker supply system here directly supplies water to people and community has no storage tanks (Jojos).

Although a first come first serve basis is still followed whereby the truck makes a halt at every street and household members queue to collect water. Water collection is limited at 3*250 litre drums at most. Water supply duration into standpipes of the households across all surface water (Hout dam) dependent communities was an average of 1 or days per week for 9 to 10 hours, which is potentially a better supply duration than the groundwater dependent communities further away from the river bed. Across most groundwater dependent communities, the supply system through overhead tanks were shared amongst two or three communities to improve and sustain water availability. Although households reported that such system has rather reduced their water security. For example, in a closed network between three communities: Ga-Hlahla, Setate and Matikering, one particular overhead tank was shared between Ga-Hlahla and Setate, while another between Setate and Matikering. Although these communities had extra boreholes those have been non-functional for years, further reducing water supply to the communities.

Social resources available to the households depends on terms of relationship amongst community members, neighbours and inter household relationships. Social resources were understood in terms of lost opportunities and social networks available to households. Females described the activity of fetching water as strenuous and that it takes a toll on their health and deprives them of having any social life. Some females reported about joint pain in legs and tiredness over time. A child who fetches water for his household described the activity as something he is used to doing and manages between schooling and fetching water after returning from school. 34% of survey respondent reported of tiredness due to fetching water and 28.5% survey respondents reported that children and young adults sometimes miss school and education due to lack of water and or has to go fetch water leading to missed education. 33% of survey respondents also faced conflicts amongst neighbours while borrowing, sharing and lending water in the past one month. Conflicts amongst community members are higher in communities where the only access is at community standpipes or tanks (Jojos). Households described the activity of fetching water as difficult and worrisome. 23% of the survey respondents showed worry about the safety of themselves or their household members who goes to fetch water. Households reported that lack of water led to disputes within the households most times leading to a poor living standard and personal wellbeing. A female survey respondent was observed as referring to such situation as:

"*The tanker which comes to fill water at Jojo (community tank) is 8000 litres and the Jojo is 10,000 litres in size. Therefore, the Jojo is never completely full…Oh! there are constant arguments for collecting water at the Jojos. The collection is based on a first come first serve basis and most people work or are not at home and uninformed of tanker arrival and hence fail to collect sufficient quantity required*" (Survey Interview, Dendron, June 2019).

Most households borrowed water when required but the act of borrowing and sharing water was also undermined by personal relationships. Some communities, where households had personal boreholes were observed and reported to sell water. A household in the community of Manamella, with borehole reported of taking money for diesel to run his pump to abstract water from borehole and thus selling it at lower cost than others. Therefore, water was observed to be a source of income amongst the well to do households amongst the communities. Many households also reported of not taking money for water and sharing it out of goodwill and as a support rather than a monetary source. In one community, it was observed that a household has their own borehole and has been sharing a substantial amount of water with their neighbour who is using it for building their house. When asked, both households reported of having a good relationship and that money is not involved in the water transaction whatsoever. The opposite of such good will was also observed across various sections of communities, whereby neighbours have stopped providing water to regular borrowers and or households themselves have stopped asking for such borrow. Social network of households being able to borrow water was understood in terms of number of households they can access or ask to borrow water. While majority of households (75%) reported that they had less than 2 neighbours to ask/ borrow water from, they also reported about the relationship between themselves. It was also observed that households would borrow water from far apart households if their neighbours were less willing to support. A female respondent described her relationship with her neighbour as:
"*I don't ask for water from them (neighbour) unless emergency…they have a Jojo and buys water to fill their Jojo. Sometimes they do not want to share water and that makes us argue…. they don't take money from me but I don't feel ethical to borrow water without money*". (Survey Interview, Ga-Hlahla, June 2019).

Perceived water quality was also observed as a major source of concern amongst many communities. Dendron, in Molemole municipality had the majority of water quality issues, where respondents complained of smell, turbidity and highly saline water from their standpipes. Other communities also showed some concern about water quality in terms of colour, odour and salinity. Households reported to access unsafe sources (ponded water, river water, etc.) during times of emergency and water scarcity. Some houses with boreholes also reported their groundwater from the borehole to be saline and turbid. Although people perceived the quality to be unsafe, no water treatment measures were taken at household level. When asked about boiling of water before use, respondents observed it as an unnecessary cost of electricity or gas. A female survey respondent voiced her issues about water quality as:
"*Yes, sometimes we have stomach aches but we are not sure if it is because of the quality of water, although the water in the standpipe is very salty…but municipality does not help in treating the water. We do not want to spend money on buying water filters or waste electricity by boiling water...*" (Survey Interview, Dendron, June 2019).

5.3.7 Discussion on key associates across qualitative and quantitative findings

Based on comparative qualitative and quantitative findings the key factors and pathways leading to household water insecurity are highlighted below.

The three domains of water insecurity within the study area were observed to be those of water access, water quality and lost opportunities and social networks. These three domains were obtained as through the perceived water insecurity scale items and further validated against physical determinants of water insecurity. Such correlations highlighted the pathways to water insecurity. 90% of the surveyed households had a piped connection within their household premises but data obtained and statistical analysis shows a clear variability amongst the studied households. Therefore, the household (HWI) scale developed portrays other key determinants of water (in)security beyond piped access to water in a complex CHANS dominated waterscape. Qualitative findings also suggested that a piped connection within household premises does not guarantee water security for households. Legality of a worked connection, economic strength of a household, the topography of the location, water pressure is some of the factors that undermine adequate water access pathways. Duration of water supply to a piped connection is another determining factor to water (in)security. Frequent and extended water cut-offs and no fixed delivery day and time leads to further conflicts in terms of water access through the standpipes within household premises. Also, through qualitative findings, people highlighted that flow rate at the standpipes were highly variable and unreliable. Regression results portrayed households with piped access to be slightly more secure as compared to those who does not have such system. Although in terms of relationship between water quantity and water quality at the standpipes, an interesting relationship was observed. Households tend to depend on standpipe water as their primary source and even if they perceive obtained water to be of poor quality, they end up using such sources for various domestic purposes including cooking, thus increasing water insecurity in terms of health issues reported to be as stomach aches and tiredness. As such due to failed and unreliable water access to standpipes, households have to look for various communal and or other sources to fetch water. Therefore, both through regression results and qualitative findings, longer time and number of trips required by household member to fetch water, increases the water insecurity for households. Generally, this task is upon the female and sometimes the children of the house. Therefore, with longer time to fetch water affects female's personal wellbeing and also provides them with lesser time and resources for food production, leading to water and food trade-offs and or reduction in food consumption. Economic strength of a household plays another important role here. Water affordability is better pronounced in higher income households. Low income households which depend solely on social grants make water and food trade-offs by purchasing food in times of uncertainties as compared to purchasing water and or water storage mechanisms. Therefore, both qualitative and statistical results highlight that with increased income, hardships decrease. In terms of other physical resources such as quantity and storage at household-level, results showed increased storage leads to increased water and food security within households. This highlights the importance of storage mechanisms such as bigger drums and jojos in a semi-arid climate to tackle water uncertain situations. Although a lack of will, interest and finance were observed across households to do so. Regression results highlighted households which has purchased additional storages over time to be more secure than those who have not. In terms of emotional distress related to water insecurity there is a significant relationship between a poor quality of life as perceived by households and their subsequent water and food insecurities. Qualitative findings also suggest the conflicts within household and communities dealing with fetching water leads to unsatisfactory wellbeing and mental stress.

SUMMARY

This section highlights the various water and related food insecurity parameters and pathways in the rural and peri-urban communities of the study area. A reliable and validated water insecurity scale was built from bottom-up to assess the pervasiveness of lived experiences at a household-level. This section also highlights the multi-dimensionality of water security through the three identified domains of household water insecurity. Perceptions about poor water access plays the most important role to water and related food insecurity for the households within the study system. In terms of water access, household's ownership of a working piped connection is not a measure of water security and the results portray a high variability amongst households. Beyond the domain of water access, poor water quality and lost opportunities are other significant physical and emotional distress related domains to defining water insecurity. Through the results of previous sections, it can be observed how institutional frameworks and climate variability plays a role in water access to the study area communities. In this section it is highlighted as to how access to water sources plays the most significant role leading to water insecurity across the communities of the study area. Therefore, it is important to also understand household's perception to willingness to pay for water services in order to improve their water security. This has been further studied and results are as shown in next section.

5.4 Household willingness to pay for water services

The willingness to pay (WTP) survey was conducted via a choice modelling and choice card experiment. A total of 66 households were surveyed across the two selected communities. The household head was always selected for survey. A brief on socio-demographic and water use characteristic of every household was first asked for and then each household head was presented with four choice cards. Each choice card had two alternatives on selected attributes and respondents were asked to select one of the alternatives on every card. A brief of socio-demographic household characteristics is presented in Table 11. 67% of surveyed household heads were female and remaining were male respondents.

Table 11 Household characteristics for WTP survey (n = 66)

VARIABLES	Category	DISTRIBUTION (N)
Average age		45.31
Gender	Male	33%
	Female	67%
Quantity of water used (in LPCD)	< 25 LPCD	42%
	> 25 LPCD	58%
Quality of water used	Perceived good quality of water	33%
	Perceived poor quality of water	67%
Average frequency of water supply at household standpipes (in hours/day)		5.23
Average last water tariff paid (in Rands/ month)		256.57
Average storage capacity of household (in litres)		195.42

(Source: Author, 2019)

Four water attributes: quantity, quality, frequency and price of water were chosen for the WTP survey. Twenty-five water alternatives and or set of attribute levels were reproduced based on orthogonal statistical design in SPSS. The orthogonal design had a D-efficiency and thus helped in reducing the number of attribute and level combinations by producing the primary effects between them. Based on the orthogonal design results thirteen choice card containing two alternatives in each card were reproduced. Four sets of such choice cards were shown to every respondent wherein they highlighted their choice of attribute set in each card. A conditional logit model (CLM) was used for statistical analysis of collected data through the choice cards. The CLM was run using statistical software SPSS and STATA, wherein the dependent variables were the water alternative choice as a combination of attributes' levels. The explanatory variable for the logit regression model were the choice attributes of water services. Tables 12 and 13 shows the CLM statistical results for the groundwater and surface water dependent communities respectively. The estimated co-efficient of the CLM regression are shown in Figures 12 and 13. The scripts used for WTP survey analysis are as shown in

Appendix F. As per *priori* expectations as highlighted in Table 1 previously, all attribute coefficients were positive except for price, thus indicating a higher price is not favoured by the communities. Increase in other attributes of quantity, quality and frequency of water supply had positive coefficients thus indicating a desirable likelihood amongst surveyed communities. Antilog of the standardised coefficients were calculated to highlight the probability of water service alternative as preferred by respondents. Implicit prices were calculated as a ratio of attribute coefficient to the price coefficient. The calculated implicit prices thus highlight the willingness to pay value for each level of attribute change respectively. The overall performance of the regression models was analysed by checking for the R^2 values. Both regressions had acceptable R^2 values for 0.21 and 0.24. This is considered good for many such similar studies (Louviere *et al.*, 2000; Snowball *et al.*, 2008).

Table 12 CLM results for groundwater dependent households in Dendron (n = 32), R^2 = 0.21

VARIABLE	**ANTILOG OF COEFFICIENT**	**IMPLICIT PRICE**	**P VALUE**
QUANTITY OF WATER	1.20	0.24	0.011
QUALITY OF WATER	8.82	2.8	0.004
FREQUENCY OF WATER SUPPLY	1.7	0.74	0.019
PRICE OF WATER	2.1	1	0.020

(Source: Author, 2019)

Table 13 CLM results for surface water dependent households in Ga-Mammadila (n = 34), R^2 = 0.24

VARIABLE	**ANTILOG OF COEFFICIENT**	**IMPLICIT PRICE**	**P VALUE**
QUANTITY OF WATER	1.36	0.11	0.051
QUALITY OF WATER	10.63	0.79	0.012
FREQUENCY OF WATER SUPPLY	6.29	0.62	0.039
PRICE OF WATER	19.31	1	0.000

(Source: Author, 2019)

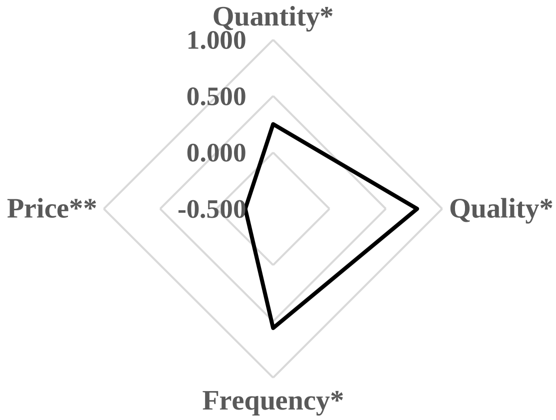

*Figure 12 CLM coefficients for groundwater dependent communities (Dendron) *significant at 1%, **significant at 5% (Source: Author, 2019)*

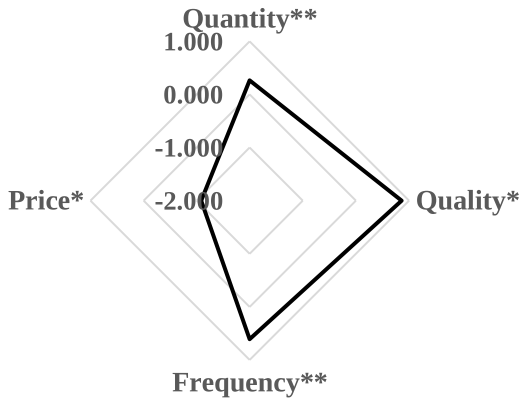

*Figure 13 CLM coefficients for surface water dependent communities (Ga-Mammadila) *significant at 1%, **significant at 5% (Source: Author, 2019)*

From Table 11, for the groundwater dependent community in Dendron, it can be inferred based on the statistical results that households are most willing to pay for improvement in water quality, followed by frequency of water supply and increased quantity of water supply at their standpipes. A WTP of 2.8 Rand/ month was reported for improved water quality. Implicit prices calculated shows that for an increase of 1litre/ day, households are willing to pay 0.24 Rands. This is equivalent to an amount of 8 Rands/ cubic meter of water. This amount is equivalent to the 2019 water tariff as per the Polokwane municipality wherein a charge of 8.31 Rand per kilo litre is levied for the first five kilo litre of domestic water supply (Polokwane Local Municipality, 2019). Frequency of water supply is also a significant determinant of households WTP, as households reported to pay 0.74 Rands for more frequent water supply. This is equivalent to 0.02 Rand/ hour of water supply. Results from Table 12, portrays the households WTP for surface water dependent community of Ga-Mammadila. The regression results highlight that all attributes are statistically significant with a highest WTP for quality of water. Households are WTP 0.79 Rands/ month for better quality of water supply to their standpipes. Households WTP for increase in water quantity was observed to be 0.11 Rand for an increase of 1 litre/day. This is equivalent to 3.67 Rand/ cubic meter of water supply. A statistically significant WTP of 0.62 Rands was observed for increased frequency of water supply, which is equivalent to 0.02 Rand/ hour.

Therefore, based on the WTP survey, the groundwater dependent community of Dendron is more willing to pay for water services and increased supply as compared to the surface water dependent community of Ga-Mammadila. Both communities surveyed had presence of piped connection, with standpipes within their household premises. The price demand/ co-efficient for water in case of surface water dependent community is higher than that of groundwater dependent community. This can be because of the economy/ average income in the surface water dependent community of Ga-Mammadila which is a former homeland is far lesser than that of groundwater dependent peri urban community of Dendron. Also, the likelihood to pay for water services in terms of water quantity is lacking in the surface water dependent community. Since they depend on the Hout dam for their water supply, the visibility of the water source makes the community members perceive water as a free resource. This observation is in line with previous qualitative findings regarding water insecurity parameters as portrayed in Section5.3.6 above. Besides, the surface water dependent community has historically never paid for water. On the other hand, the groundwater dependent community has a rigorous metered connection and are used to paying for water tariffs as per meter readings, till recent past where due to lack of water supply, the community has been on strike leading to non-payment. Both communities perceived water quality as a major determinant of household's willingness to pay. Dendron, being a groundwater dependent community perceived a much poorer water quality and hence were more willing to pay for a better quality of supplied water. On the other hand, surface water dependent community portrayed water quality as an issue during limited supply from the Hout river dam, wherein households depend on unsafe water from the river beds and other smaller ponded water bodies in vicinity. Frequency of water supply was determined as another important determinant, although both communities were willing to pay the least as compared to quantity and quality of water. Across both communities an average of 5 hours of water supply per day takes place through the household standpipes. This could be interpreted as a perception of water availability by households are more related to reliability when it comes to paying for water services as compared to frequency.

Therefore, the current WTP survey portrays households unsatisfaction with current level of domestic water provision. Quality of water services plays an important role in household's WTP in terms of water sources. Lack of sufficient water quantity for domestic uses not only drastically reduces current livelihood of households but also affects their ambitions and willingness to improve their status. Choice modelling therefore helps in highlighting water user's stated preferences and respective WTP for several different water service characteristics separately. Such information can further advance policy implications. The survey and corresponding statistical results highlight a WTP across both communities where the local municipalities have been successful in providing piped connection through household premises. The WTP survey also shows that preferences and WTP varies across several attributes for different communities. Therefore, the adoption of cost recovery mechanism may be successful if local municipalities can adhere to such needs and further improve the water service delivery and supply. Further, adoption of tariffs and technological interventions if done on a case by case basis as per the needs and demands of the rural and peri-urban communities, the success of cost recovery may have higher probability in near future.

SUMMARY

This section portrays household's willingness to pay for water services in terms of quantity, quality and frequency of water supply. The WTP exercise was carried across via choice modelling survey across two communities, one being surface water dependent and the other being groundwater dependent. Both communities had presence of piped connection through standpipes within household premises. Therefore, the aim of this survey was to understand if cost recovery mechanisms is a viable technique across such communities, where the local municipalities have indeed improved water service and supply through presence of standpipes. Data collected through choice model survey was analysed statistically using logistic regression.

Groundwater dependent communities are more willing to pay for increased water quantity as compared to surface water dependent communities. Water quality was perceived to be the most important determinant of household's WTP across both communities. Both communities allocated higher relevance to water quality improvement as compared to better frequency of water supply. This is due to the strong concern across households regarding the poor quality of water collected. The groundwater community has poor service of water quality delivered to them as the standpipe water is highly saline, turbid and sometimes has odour. On the other hand, households in surface water dependent communities fall back upon unsafe sources of water such as river beds and small ponded water bodies, when there is cut-off and lack of supply form the Hout dam. The calculated WTP across both communities shows that irrespective of a highly varied socio-economic and socio-demographic characteristic both communities are willing to pay for water services. Therefore, the dialogue of cost recovery through local municipalities may be a successful phenomenon if the local municipalities can take a case by case mechanism across rural and peri urban communities, keeping in mind the needs and factors that affect each community.

5.5 Coupled human and natural system pathways and feedbacks

Under the scope of the present research, water insecurity at the household level was defined in a two-fold way. Wherein the inability to access and benefit from affordable, adequate, reliable and safe water for wellbeing and healthy life and consequently the inability of a household to accept and or adapt to hydrological and ecological changes shall lead to a state of water insecurity. Having analysed the various socio-economical, socio-hydrological, socio-ecological and institutional frameworks separately, the lens of a coupled human and natural system (CHANS) framework, allows understanding the possible feedbacks and pathways of each respectively, that may lead to household-level water and related food insecurity. The linkages between these factors are as shown in Figure 14.

Socio-hydrological and socio-ecological feedbacks

Climate change and variability shall lead to increased temperature, decreased wet season and decreasing amount of rainy days as observed from the statistical analysis of past climate data. Subsequent hydrological changes within the study system shall lead to increased sporadic extreme events of rainfall and droughts. The rural and peri-urban communities within the study system are heavily dependent on groundwater sources for their livelihood, wellbeing and domestic uses. Over-dependence on groundwater and extreme stress on the groundwater aquifers due to improper maintenance of domestic water supply systems (i.e. running communal boreholes for extended periods to fill communal tanks) shall lead to decreased groundwater resources in short and long term. Additionally, over-abstraction of groundwater by downgradient commercial farmers puts additional pressure on the groundwater aquifer systems. Limited rainfall and high evapotranspiration and surface runoff rates allow for limited recharge to these aquifers, thereby further stressing the supply systems. Surface water-dependent communities who are supplied water from the Hout dam also stand a chance of limited water supply in near future, given the lack of capacity of the reservoir to maintain a high supply-demand ratio. The reservoir is an earth dam and has observed significant siltation since its inception, thus further reducing its capacity over the years. A significant decrease in dam level also has been observed in dry periods (1.7 meters in the last four years, as observed from the daily logbook at the dam premises). Hence climate change in the near future shall lead to decreased performance of both the groundwater and surface water-dependent water supply schemes creating negative feedback if adequate measures are not adopted at present. Short- and long-term positive feedbacks may occur if local and provincial governments adopt more thorough and extensive ways of disseminating climate information to farmers and help in producing accessible means of early warning procedures. Additionally, increased awareness amongst both commercial and smallholder farmers through dissemination of groundwater management data, more active monitoring methods of groundwater, helping create a local Water User Association (WUA) may lead to improved and sustainable management of groundwater sources and act as long-term positive feedbacks to increased water security.

Increasing population density and informal settlements across the Hout river bed (i.e. the community of Jerusalem within the study system as mentioned earlier in Section 5.1) further acts as stressors to the water supply schemes, reducing its performance. The local municipalities agreed that over-dependent groundwater supply scheme and increasing population which is not adequately captured in census data are major drivers to water security. The local municipalities proclaimed that a lack of proper reticulation and supply system has constituted a significant hindrance to a fluent water supply network at present. Although a possible long-term positive feedback to improve domestic water supply and access in near future may occur if an improved supply system of communal tanks and reservoirs as planned and portrayed in the IDP of the local municipality of Polokwane gets effective.

Institutional mechanism feedbacks

An integrated top-down and bottom-up approach to institutional framework analysis helped understand the lack of coherence amongst the traditional and local governance in the rural homeland communities. There exists a lack of trust between citizens and the traditional governance systems in the former homelands. Favouritism by chiefs at times leads to the benefit of selected few in these already marginalized communities. Therefore, the households are stuck in a prisoner’s dilemma of water without land and vice versa. It was also observed that a lack of awareness amongst communities and a lack of dependence and trust between the local government and the citizens further leads to increased conflicts and vandalism of water resources. Lack of effective operation and maintenance in combination with the lack of trust between these various stakeholders further aggravate household-level water insecurity. Lived experiences as observed thus portrayed a short-term negative view on the state of water security thus highlighting a negative feedback amongst stakeholder relationships.

At present based on the survey and subsequent empirical evidences, households perceived water insecurity as a result of three dimensions: poor water access and quantity, poor water quality and increased emotional distress. It was also observed that these dimensions subsequently lead to household food insecurity as a result of household water insecurity. Although 90% of surveyed households within the communities had piped water access, the developed HWI scale portrayed a wide diversity in terms of water security and or insecurity. Hence regardless of increased provision of safe water through piped systems by the local governments in recent past under the FBW act, households are still water insecure in terms of water access and reliability. This finding supports similar inferences in *colonias* of US-Mexico border, wherein Jepson (2014, p. 117) highlights "water connections are available, if residents can afford them; however connections do not guarantee water quality or adequate service". Domestic water provision in the surveyed communities depends on age-old (i.e. ranging from 35 to 45 years) pre-apartheid communal water tanks and reticulation systems. Post-apartheid under the decentralized water governance, although a handful of new tanks has been built, the local government's lack of capacity to maintain such water infrastructures and meet demands of growing population or face challenges of unregulated and informal water arrangements are underlying factors to increased household water insecurity. Therefore, piped supply may act as a positive feedback mechanism only when supply and infrastructure is subsequently well maintained and improved. Such improvements in due time shall also increase stakeholder relationships with positive views and feedbacks.

Socio-economics and physical factor related feedbacks

Due to lack of adequate access and poor quality of supplied water, households take to other sources (i.e. buying water, borrowing water or relying on unsafe sources). Therefore socio-ecological, socio-hydrological and institutional stressors underline and define household water insecurity. Through the HWI scale diverse perceptions were captured across the surveyed communities. Affordability and household's incomes help improve household's water security status. Affordability also lead to increased motivation to increase storage mechanisms. Households also depend on communal sources and social networks of borrowing water from within community members. Therefore, increased water insecurity leads to increased deuteriation in quality of life, emotional distress and food insecurity. Hence negative socio-ecological-hydrological feedbacks lead to negative views of societal experiences and responses.

A diverse socio-economy was observed within the surveyed communities, wherein poor households living on meagre social grants were the most water insecure. On the other hand, households with improved financial status also strive to maintain their water security in terms of water access and reliability either by relying on private tankers or buying water from other sources. Households who have adapted to the situation by drilling their own borehole and increased storage facilities were observed to be the most secure. However, such adaptation strategy may affect water insecurity negatively in a long-term by further stressing the groundwater aquifers resulting in a negative feedback. Households with increased storage capacity also were observed to be moderately water-secure depending on water access and economic strength of the household. A positive feedback may hence be promotion of increased storage devices and simultaneously proper maintenance of water supply infrastructure and systems may reduce existing water insecurity and create better trust mechanisms between the citizens and the local municipalities. This may also help improve societal networks and reduce communal conflicts related to water supply at communal sources. Water quality as obtained through piped supply also act as a stressor to increased household water insecurity. Reduced water quantity and poorly perceived water quality status thus act as pathways to further increase negative views and societal responses.

The local governments also are set back in terms of economic strength and personnel to provide adequate operation and maintenance of existing water infrastructure and supply systems. Thus, failure of cost recovery also acts as a hindrance to increasing water security in these regions. Therefore, a decreased supply and poor reticulation lead to increased household water insecurity across the rural and peri-urban communities of the study system. Through the household's willingness to pay survey across one groundwater and one surface water-dependent community, it was portrayed that the communities are willing to pay for water services in order to get treated water and increased quantity at their standpipes. Therefore, an adequate system crafted based on the socio-economic strength of these communities and levying a flat rate for water services through metered water access may improve cost recovery scenario across these communities. Improved cost recovery shall act as positive feedback and in both short and long-term and shall help improve water security in these water landscapes which are dominated by socio-political-environmental systems. This in turn can improve societal views and responses regarding local governments.

A detailed conceptual diagram to help understand these feedbacks as observed in the rural and peri-urban communities of Hout catchment is as shown in Figure 15.

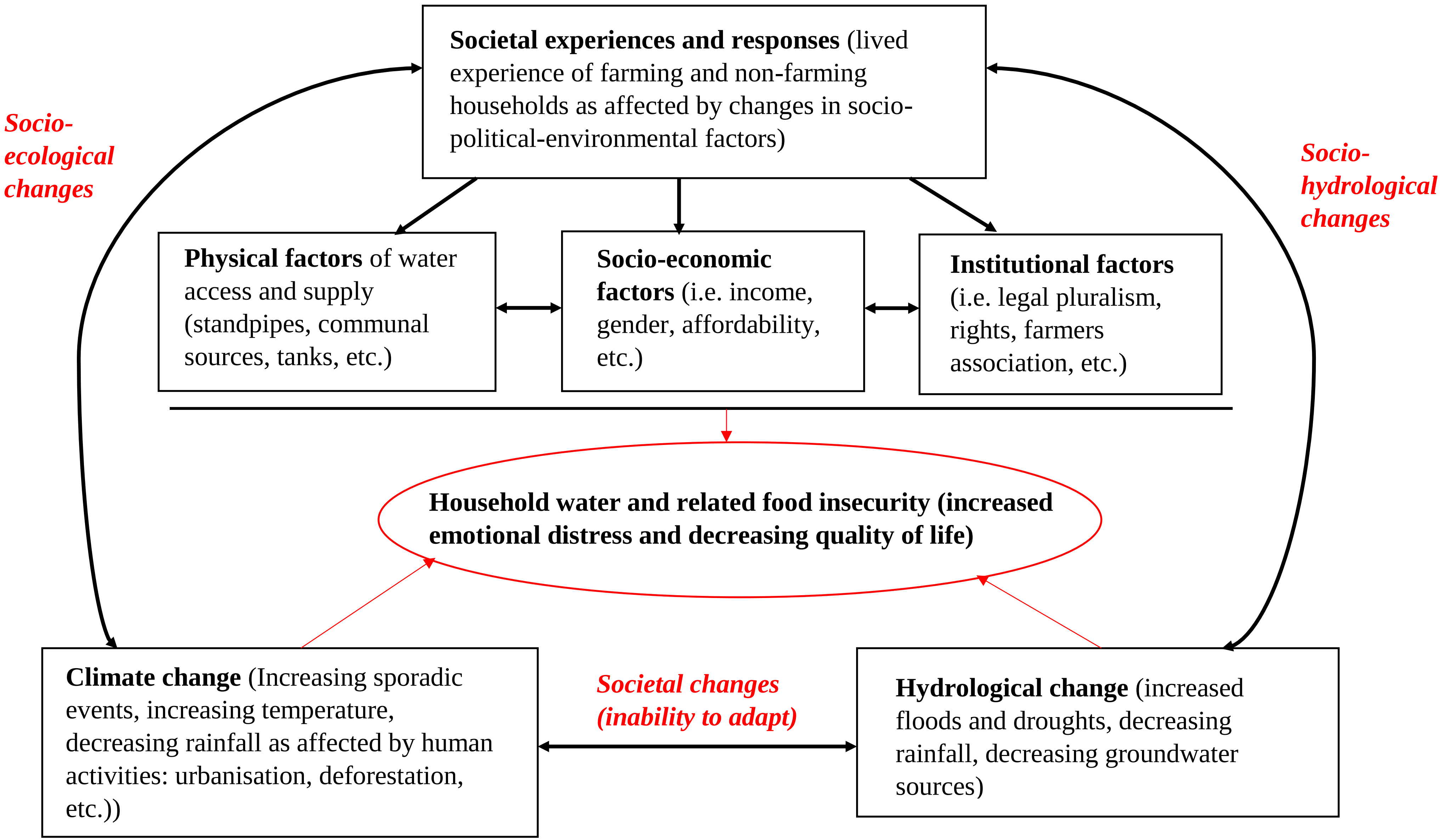

Figure 14 Linkages between socio-ecological, socio-hydrological, socio-economical, physical and institutional factors leading to household water and related food insecurity (red arrows indicate failure of each factor leads to a status of insecurity) (adapted from: Danielaini et al.*, 2019 and Sinyolo* et al.*, 2014)*

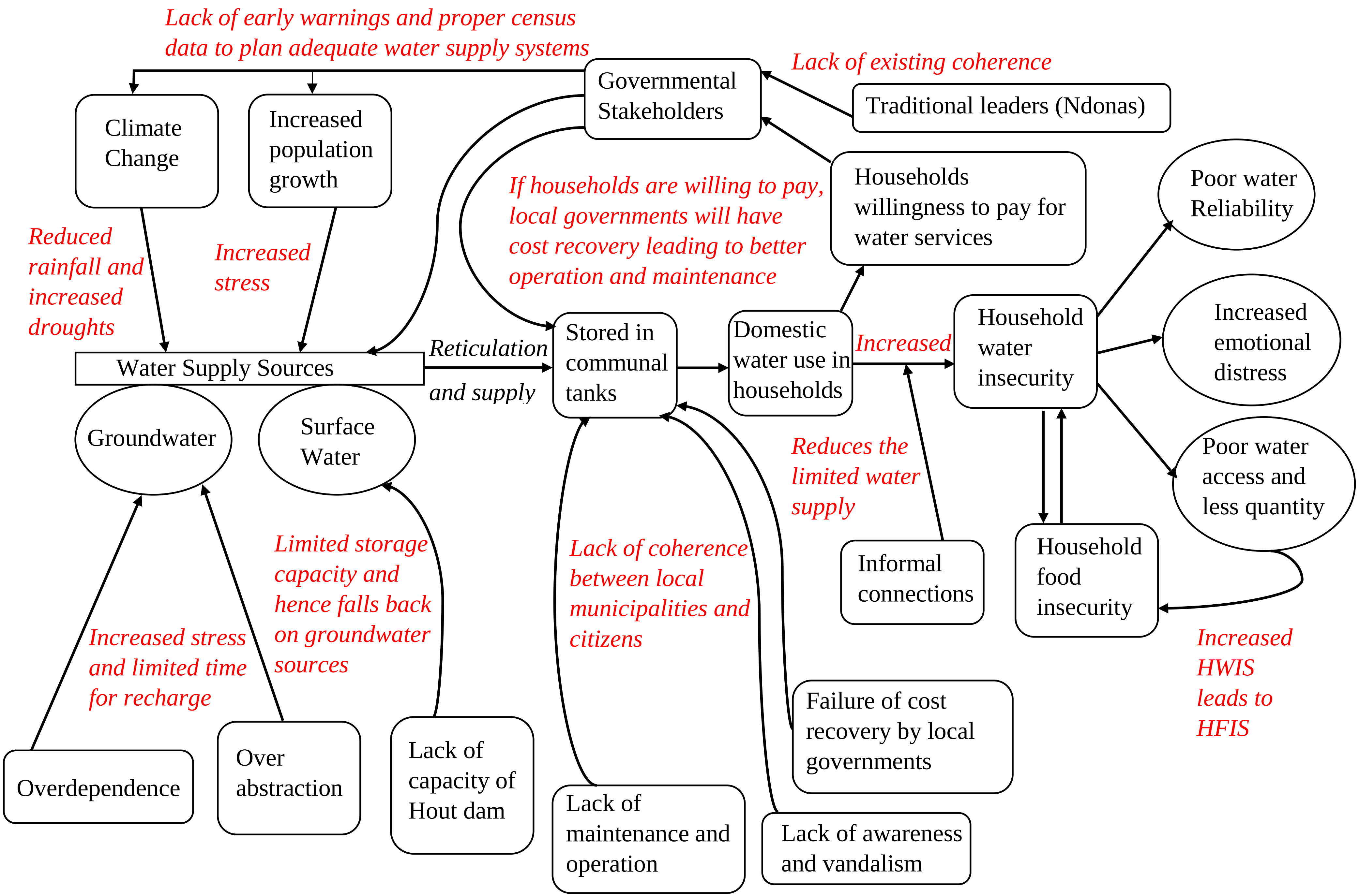

Figure 15 Conceptual diagram of pathways to household water insecurity in a coupled human and natural system (CHANS) illustrating the linkage between social, ecological, economical and physical dimensions (Source: Author, 2019)

CHAPTER 6

Conclusion

Through the present research scope, I intended to identify the key determinants to household-level water insecurity in rural and peri-urban landscapes of the Hout catchment, in the Limpopo basin of South Africa. The research investigated the institutional frameworks, climate, perceived state of water insecurity and household's willingness to pay for water services that may affect a households' water security in a coupled system. I then applied the lens of CHANS approach to link them together in the broader context of interacting social, ecological and institutional drivers to infer on pathways, short-term and long-term feedback of these parameters leading to household-level water security and or insecurity in rural and peri-urban landscapes within my study system.

To study the perceptions of water (in)security at a local level, I took households as study units. and formulated an experience-based household water insecurity (HWI) scale to portray household's lived emotions. The bottom-up, micro-level household water insecurity scale focused not only infrastructure but also the socio-economic, political and emotional aspects of human wellbeing. The novelty of the research is thus derived from the application of such an approach in the rural and peri-urban landscape of South Africa to a broader sense of water (in)security by combining experiential and physical dimensions. A mixed quantitative and qualitative approach through an item-based, cross-sectional household survey and subsequent statistical analysis of survey data was conducted to understand the key determinants of household level water insecurity. Empirical evidences highlighted three dimensions of perceived water insecurity: perception of water access issues, perception of unsafe water and perception of lost opportunity costs and social network. Therefore, the developed scale helped advance the idea of multi dimensionality of water insecurity as highlighted in previous researches (Stevenson *et al.*, 2012; Jepson, 2014; Ahira *et al.*, 2015).

As opposed to general macro level water insecurity metrics, the developed HWI scale further helped to explain latent constructs of water insecurity at the local level. Besides water access in terms of quantity and water reliability in terms of quality it highlighted emotional wellbeing, quality of life, socio-economy in terms of social networks within the community and lost opportunities for economic wellbeing. The scale therefore portrayed that at micro level lived experiences of water (in)security vary widely. Groundwater dependent communities and surface water dependent communities portray their lived emotions differently. Similar water insecurity is perceived differently across gender and within different households of the same community. The state of water security and or insecurity as a snapshot in time thus vary depending on factors such as: quantity, access, quality and emotional distress. The research also highlights that perceptions of households also depended on knowledge and how they use it to be aware and or create awareness. Socio-economic capacity of a household and household's willingness to adapt to uncertainties plays a crucial role in reducing water insecurity. Results portrayed that socio-hydrological and socio-ecological factors are important stressors to securing water security at household level in the study site communities. Climate change leading to more extensive warmer periods, reduced rainfall and increased droughts shall further stress the existing domestic water supply schemes in near future. Institutional frameworks portrayed the existing differences across various actors involved.

Therefore, in a CHANS framework all these factors combined lead to negative views and societal responses through individual's lived experiences in such complex water landscape. Increasing water insecurity at household level leads to a poor quality of life as highlighted through increased emotional distress of the HWI scale. Cost recovery mechanism may be an effective solution in both short and long term to improve water access and infrastructures. This simultaneously shall improve stakeholder relationships and positive views amongst the local municipalities and citizens. Household's portrayed a varying degree to willingness to pay for water services. Although a positive WTP highlights household's eagerness to improve the waterscape. Therefore, adoption of water meters and an affordable flat rate as per the socio-economy of the rural and peri-urban communities may act as a positive intervention. Further awareness across communities and inclusion of communities in water provisioning and planning shall lead to improved relationship between the local municipalities and citizens and shall prevent vandalism. Improved water monitoring from the DWS and better dissemination of climate and groundwater data across farmers shall help create awareness and improved management. Inclusion of citizens through volunteering projects and citizen science activities may further such causes and bridge the gap between the various stakeholders.

Limitations within the present research scope are firstly that of sampling size and time. Given the research period, a random and cross sampling method was undertaken. Although households with varied sources of water supply and scenarios were surveyed, sampling size was not statistically calculated. Secondly, in willingness to pay survey, only two communities were approached. Although the two surveyed communities were chosen based on a worst-case scenario of water insecurity scale scores, a detailed survey across all communities would provide a holistic picture. The research shows the usefulness of developed metric in understanding and analysing perceptions of individuals and or households at a local scale. Further development of such metric is required in South Africa to understand in detail the citizen – local municipality relationships and issues regarding water (in)security within the nation. Given the independent nature of local municipalities in South Africa, use of such perception-based scales across the several municipalities shall bring forth the varied issues which can be effectively and mutually solved to reach sustainable solutions. Additionally, such perceptions should be characterized in terms of broader influencing factors to govern effective policy making in the future. The developed HWI scale can be further implemented and developed to study the effectiveness of intervention measures in water access pathways. The research also validates the co-dependency of water and food insecurities in rural and peri-urban landscapes and hence future studies should focus on both parallelly. Studies should also focus on gender-based dimension within same household to further elucidate the varying perceptions at local levels.

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Appendices

Appendix A: Script for climate analysis (ggplot and regression)

Seasonal Total rainfall

```
df = final
lm_fit1<-
lm(seasonal_rainfall_total~year+seasonal_total_rainfall_wet,da
ta=df)summary(lm_fit1)predicted_df<data.frame(seasonal_rainfal
l_total_pred=predict(lm_fit1,df),seasonal_total_rainfall_wet=d
f$seasonal_total_rainfall_wet)
library(ggplot2)
ggplot(data=df,aes(x=year,y=seasonal_total_rainfall_dry))+geom
_point(size=1.5,aes(color=name)) + geom_smooth(method="lm",
color='black', se=TRUE, level=0.95, size=1) + theme_classic()
+ theme(axis.title = element_blank(), legend.title =
element_blank()) + coord_cartesian(xlim =c(1960, 2015), ylim =
c(0,900))
lm_fit2<-
lm(seasonal_rainfall_total~year+seasonal_total_rainfall_dry,da
ta=df) summary(lm_fit2) predicted_df <-
data.frame(seasonal_rainfall_total_pred = predict(lm_fit2,
df),seasonal_total_rainfall_wet=df$seasonal_total_rainfall_wet
)
library(ggplot2)
ggplot(data =df, aes(x=year, y=seasonal_total_rainfall_wet)) +
geom_point(size =1.5, aes(color=name)) + geom_smooth(method =
"lm", color ='black', se = TRUE, level=0.95, size=1) +
theme_classic() + theme(axis.title = element_blank(),
legend.title = element_blank()) + coord_cartesian(xlim
=c(1960, 2015),ylim = c(0,900))
```

Number of rainy days/ seasons

```
df = final, lm_fit3 <- lm(rainy_days_tot ~
year+rainy_days_wet, data = df)
summary(lm_fit3), predicted_df <-
data.frame(rainy_days_tot_pred = predict(lm_fit3,
df),rainy_days_wet=df$rainy_days_wet)
library(ggplot2)
ggplot(data =df, aes(x=year, y=rainy_days_wet)) +
geom_point(size =1.5, aes(color=name)) + geom_smooth(method =
```

```
"lm", color ='black', se = TRUE, level=0.95, size=1) +
theme_classic() + theme(axis.title = element_blank(),
legend.title = element_blank()) + coord_cartesian(xlim
=c(1960, 2015),ylim = c(0,50))
lm_fit4 <- lm(rainy_days_tot ~ year+rainy_days_dry, data = df)
summary(lm_fit4), predicted_df <-
data.frame(rainy_days_tot_pred = predict(lm_fit4,
df),rainy_days_wet=df$rainy_days_wet)
library(ggplot2)
ggplot(data =df, aes(x=year, y=rainy_days_dry)) +
geom_point(size =1.5, aes(color=name)) + geom_smooth(method =
"lm", color ='black', se = TRUE, level=0.95, size=1)+
theme_classic() + theme(axis.title = element_blank(),
legend.title = element_blank()) + coord_cartesian(xlim
=c(1960, 2015),ylim = c(0,50))
```

Rainfall Intensity

```
df = final
lm_fit7 <- lm(rainfall_intensity_tot ~
year+rainfall_intensity_wet, data = df), summary(lm_fit7),
predicted_df <- data.frame(rainfall_intensity_tot_pred =
predict(lm_fit7,
df),rainfall_intensity_tot=df$rainfall_intensity_wet)
library(ggplot2)
ggplot(data =df, aes(x=year, y=rainfall_intensity_wet)) +
geom_point(size =1.5, aes(color=name)) + geom_smooth(method =
"lm", color ='black', se = TRUE, level=0.95, size=1)+
theme_classic() + theme(axis.title = element_blank(),
legend.title = element_blank()) + coord_cartesian(xlim
=c(1960, 2015),ylim = c(0,50))
lm_fit8 <- lm(rainfall_intensity_tot ~
year+rainfall_intensity_dry, data = df)
summary(lm_fit8), predicted_df <-
data.frame(rainfall_intensity_tot_pred = predict(lm_fit6,
df),rainfall_intensity_dry=df$rainfall_intensity_dry)
library(ggplot2)
ggplot(data =df, aes(x=year, y=rainfall_intensity_dry)) +
geom_point(size =1.5, aes(color=name)) + geom_smooth(method =
"lm", color ='black', se = TRUE, level=0.95, size=1)+
theme_classic() + theme(axis.title = element_blank(),
legend.title = element_blank()) + coord_cartesian(xlim
=c(1960, 2015),ylim = c(0,50))
```

Coefficient of Variation

```
df = final
lm_fit5 <- lm(seasonal_variability_tot ~
year+seasonal_variability_wet, data = df), summary(lm_fit5),
predicted_df <- data.frame(seasonal_variability_tot_pred =
predict(lm_fit5,
df),seasonal_variability_wet=df$seasonal_variability_wet)
library(ggplot2)
ggplot(data =df, aes(x=year, y=seasonal_variability_wet)) +
geom_point(size =1.5, aes(color=name)) + geom_smooth(method =
"lm", color ='black', se = TRUE, level=0.95, size=1) +
theme_classic() + theme(axis.title = element_blank(),
legend.title = element_blank()) + coord_cartesian(xlim
=c(1960, 2015),ylim = c(0,2.5))
lm_fit6 <- lm(seasonal_variability_tot ~
year+seasonal_variability_dry, data = df)
summary(lm_fit6), predicted_df <-
data.frame(seasonal_variability_tot_pred = predict(lm_fit6,
df),seasonal_variability_dry=df$seasonal_variability_dry)
library(ggplot2)
ggplot(data =df, aes(x=year, y=seasonal_variability_dry)) +
geom_point(size =1.5, aes(color=name)) + geom_smooth(method =
"lm", color ='black', se = TRUE, level=0.95, size=1) +
theme_classic() + theme(axis.title = element_blank(),
legend.title = element_blank()) + coord_cartesian(xlim
=c(1960, 2015),ylim = c(0,2.5))
```

Appendix B: Survey questionnaire

SURVEY ON HOUSEHOLD WATER INSECURITY IN HOUT CATCHMENT

This survey is being conducted at a household level across the Hout catchment. The information obtained from this survey shall help yourself, communities and planners for understanding water security issues and develop future sustainable measures to address water insecurity. The questions are to understand your perception on your household's water problems. If you choose to start the survey and choose to discontinue, there shall be no penalties/ prejudices. Therefore, would you kindly partake in this survey interview?	**Yes**	**No**

Surveyor Name		**Survey Date**	
Respondent Name		**Respondent Telephone Number**	
GPS Co-ordinates			
Time Started		**Time Ended**	

1. Socio-demographic

This section is to understand the general characteristics of your household such as household head, education level, family size, sources of income, monthly income from various sources, household assets (household utilities, e.g., tv, fridge, stove, etc. and other assets such as farming plots, livestock, etc.)

1. What is your gender?	Male	Female
2. Are you the head of the household?	Yes	No
3. If you are not the head of household, is the head a male or female?	Male	Female
4. What is the age of the household head?	<20 years	20 – 35 years
	35 – 45 years	45 – 55 years
	55 – 65 years	>65 years
5. What is the highest education level of the household head?	Never went school	Primary school
	Matric	Graduate
6. Which is the main language that you speak in your household?		
7. What is the total number of people in your household?		

8. What is the female, male and children (<16 years) ratio in your household?	Female:	Male:	Children:		
9. Do you have access to electricity in your household?	Yes		No		
10. What is your household income in total?	<1,000R	1,000 – 5000 R	5000 – 10,000R		
	10,000 – 15,000R	15,000 – 20,000 R	20,000 - 30,000 R		
11. What are the major sources of your household income and how much do you earn from each in Rands?	Agriculture/ Irrigation:		Livestock:		
Other sources of income (non-farming):					
12. If irrigation, which are the major crops that you grow?					
13. What are your other sources of income during off-season/ water unavailability times and how much do you earn from them in Rands?					
15. Mention the items that your household has and how many?	Television ( )	Fridge ( )	Stove ( )	Radio ( )	None of these
	Bicycle ( )	Motorbike ( )	Car ( )	Mobile ( )	
16. What kind of assets/plots does your household own?	Livestock	Homestead plots	Rainfed plots	Irrigated plots	Commercial plots
If not homestead, mention distance of plots from your house? In case of livestock, mention how many livestock do you own?					
17. Are the livestock and related products for household consumption/ sold in market?	Exclusively own consumption	Mainly own consumption	Equally own consumption and sale	Mainly sale	Exclusively sale
18. Are the livestock fed water within house/ outside?	At home	Outside home, specify:			

2. Household water insecurity

This section is to understand the household water insecurity through 34 pre-generated items. For each item, please answer in number of times your household has faced such a situation the last one month (30 days). If answer is 0 days = never, 1 to 2 days = rarely, 3 to 10 days = sometimes, 11 to 20 = often, greater than 20 days = always. Other options also are respondent refusing to answer to an item (refuse) and or not applicable/ don't' know (NA)

Start each question as: In the last one month, how many times did you or your household members:

ITEM No.	ITEM/ QUESTION	RESPONSE
ITEM 1	Were unable to access/ use the primary source of water use for HH	

ITEM 2	Were unable to collect minimum daily HH water demand from primary and or other sources you use	
ITEM 3	Felt worried and upset about HH water situation	
ITEM 4	HH had to drink less water than preferred	
ITEM 5	Daily routines/ chores interrupted due to water situation in HH	
ITEM 6	Did not have enough water for cooking desired meal for the HH	
ITEM 7	Did not have enough water for cleaning the HH (including cleaning utensils)	
ITEM 8	Did not have enough water for washing clothes for the HH	
ITEM 9	Did not have enough water for the HH members to remain hygienic (bath/ washing hands, face)	
ITEM 10	Did not have enough water to clean hands/ to be used for sanitation purposes for HH members	
ITEM 11	Did not have enough water to maintain crops	
ITEM 12	Did not have enough water to maintain livestock	
ITEM 13	Had to borrow water	
ITEM 14	Had to purchase water (for drinking/ washing, etc)	
ITEM 15	Had to loan water	
ITEM 16	Went to purchase water but there was no one to purchase water from	
ITEM 17	Had money problems to purchase water	
ITEM 18	Went to borrow water but there was no one to borrow water from	
ITEM 19	Had a dispute with neighbour/ other community people over sharing (borrowing/ loaning) water	
ITEM 20	Had a dispute with community members while collecting water (accessing) from a communal source/ for livestock/ crop, etc	
ITEM 21	Were worried about the safety of yourself/ HH member who goes to collect water	
ITEM 22	Children and young adults missed school/ university due to lack of water availability/ had to collect water, etc.	
ITEM 23	Had a dispute within household due to water situation	
ITEM 24	Got tired due to water collection	
ITEM 25	Had to buy food due to water unavailability	
ITEM 26	Unsatisfied with water quality from primary source	
ITEM 27	Had to drink water that was unsafe	
ITEM 28	Had health problems	
ITEM 29	Reused water	
ITEM 30	Treated water source	
ITEM 31	Disinfect containers before use	
ITEM 32	HH had no useable or drinking water for a complete day	
ITEM 33	Complained to municipality/ ward office/ tank maintenance personnel	

ITEM 34	thought about satisfaction of current HH water status	

3. Water quantity, quality, access and use

**measurement can be in terms of buckets – converted into litres by surveyor*

FOLLOWING MATRIX IS TO UNDERSTAND THE VARIOUS SOURCES OF HOUSEHOLD (DOMESTIC) WATER, USE, RELIABILITY, AFFORDABILITY, SAFETY, CONFLICT/ ARGUMENT, ETC. OF SUCH SOURCES

Source of HH water *(enumerator to explain each source and ask the HH if they use these sources, tick all that apply in order of highest to lowest preference)*	**Purpose in HH for using this source of water?**[2]	**Is this source located within the household/ is it a communal source?** *(to understand HH access to private water facilities)*	**How often has your household used this source in the last 1 month?** *(answer in no. of times 1,2,3…20...etc.)*[3] *I would have a response category rather which is 1 x a month* *More than 1 x but less than 5* *More than 5 times a month* *5 – 10 times* *10 – 20 times* *More than 20 times*	**How often has your HH faced water shortage in the last 1 month from this source?** *(answer in no. of times 1,2,3…20...etc.)* **Rather Never Rarely Sometimes (not numbers)**	**Is this source of water affected by seasonal variability?** *(Yes/ No)*	**Quantity of water abstracted from this source in the last 1 month? Unlikely the respondent would know this – I would leave it out**	**Issues faced with quantity of water from this source in the last 1 month?** *(availability, reliability, affordability, etc.)* *The water is too dirty* *It is too difficult to access this water* **This was is not available on a regular basis**	**Issues faced with quality of water from this source in the last 1 month?** *(smell, colour, salinity, toxicity, sediments, etc.)* *Delete – you can capture this in the question before – about the issues faced – rather add these concerns to this last column (the question preceding this one)*	**Does your HH: (1) Collect water quantity/ quality data from these sources?** *(Yes/ No).* **(2) Would you share?** *(Yes/No)*	**Do you share this source of water with your neighbour?** *(Yes/ No)*	**How many times have you faced an issue regarding sharing this source of water in the last 1 month?** *(answer in no. of times 1,2,3…20...etc.)*

[2] Drinking, washing clothes, washing utensils, bathing, washing hands, cooking, sanitation, gardening, recreation (swimming), selling the water/ loaning water, irrigation, livestock, others (if others, please specify)

[3] Scale: Never (0 times), Rarely (1-2 times), Sometimes (3-10 times), Often (11-20 times), Always (>20 times), I don't worry, Don't Know/ Refuse to answer.

Regional/ Local Municipal Water Scheme											
River/ Streams											
Ponded water											
Water from aboveground/ underground tanks											
Tanker supplied water											
Water bought from supermarkets											
Borewell within HH											
Handpumps within HH											
Domestic Tap Water											
Community borewell											
Community handpump											
Community Tap Water											
Open Wells											
Rainwater harvesting tanks											
Treated water from WWTP											
Household treated water											

Others:											

Please explain in brief, what steps your household takes in times of water shortage/ season variability in supply from the sources of water you use?

Source of HH water *enumerator to explain each source and ask the HH if they use these sources, tick all that apply in order of highest to lowest preference)*	**Which of these sources of water do you use for Irrigation and livestock?** *(mention I for irrigation and L for livestock)*	**How do you access this source of water?** *(mode of transport: by foot, cycle, car, etc.)*	**Distance to access source?** *(in meters/ kms/ No_ time taken to reach water source*	**Time to access source?** *(in mins)*	**Who goes to collect water from this source Do men and women collect water from these sources?**[4]	**Does your HH have to pay to use water form How much do you pay for water from this source per month**	**Who pays the cost of maintenance of these sources: Choose? 1. Paid by the HH, 2. Subsidised by the municipality, 3. Other (specify)**	**Storage capacity in HH**	**How often in the last 1 months have your quality of life got affected?** *(ans. In no. of times 1,2,3…20... etc)*	**Do you re-use any of these sources of water for your HH? (Yes/ No) If Yes, mention for what purpose? (e.g. domestic/ irrigation/ livestock)**	**Does the local committ ee take care of this source of water?** *(Yes/No)*

sources were same as above – has been cut down to reduce size of table to show in annex

4. Institutional and Socio-eco-hydrological changes

DOMAIN	ITEMS	RESPONSES	
Water Rights and Governance	**1. Does your household receive any social grant?**	Yes	No
	2. Is your household part of any irrigation scheme?	Yes	No
	3. In the last 1 month, receiving such social grant/ part of irrigation scheme has improved my household water security status?	Yes	No
	4. In the last 1 month, receiving such social grant has improved my household food security status?	Yes	No
	Is there a local water committee in your area?	Yes	No
	6. Is there a local organization/ committee in your community that helps your household with water security/ during water shortages?	Yes	No
	If Yes to Q6. Explain How?		
	7. How satisfied are you with the working of the local committee?	Yes	No
	8. Does the local committee/ municipality/ DWS monitor water quantity/ quality status in the community?	Yes	No
	If yes to Q8. How often does the collection of data take place?		

[4] Yes, men and women do, yes only women do, yes only men do, yes young girls do, yes young boys do, water is transported to home

	10. Is the data shared with you?	Yes	No					
	If yes to Q10. Does the shared data help manage your HH water supply better?	Yes	No					
	11. Which of these shall help you to be more secure in your household water status?	More training about water concerns	Regular monitoring of water quantity	Improved rights to water				
		Access to groundwater data	Regular monitoring of water quality	Other (specify):				
Ecohydrological Changes (CC, Hydrological changes, Adaptation and management)	**1. In last 10 year has seasonal and annual climate variability affect your household water supply and demand? (increase in no. of hot days/ days with no rainfall, etc.)**	Never	Rarely	Sometimes	Often	Always	Don't worry	Don't Know
	2. Does climate variability affect groundwater levels in your area?	Never	Rarely	Sometimes	Often	Always	Don't worry	Don't Know
	3. Has your household noticed any change in temperature in last 10 years?	Never	Rarely	Sometimes	Often	Always	Don't worry	Don't Know
	4. Has your household noticed any change in rainfall in last 10 years?	Never	Rarely	Sometimes	Often	Always	Don't worry	Don't Know
	5. Has your household noticed any change in land use in your farms/ community in last ten years?	Never	Rarely	Sometimes	Often	Always	Don't worry	Don't Know
	6. Tick all changes you have noticed in groundwater in last 10 years?	Borewell water has decreased last 10 years	Borewells have insufficient water	Borewells have run dry	Groundwater has become toxic/saline in certain areas	I have to walk/ travel more to access groundwater for household	Others (specify):	
	7. When was the last severe drought in your area?	Less than 6 months ago	Within last year	Two years back	Others (specify):			
	8. Did it affect your household water status?	Yes	No					
	9. When was the last severe flood in your area?	Less than 6 months ago	Within last year	Two years back	Others (specify):			
	10. Did it affect your household water status?	Yes	No					
	11. Are you preparing for a next drought/ flood for ensuring your household water security?	Yes	No					
	12. How satisfied are you on a scale of 1 (lowest) to 5 (highest) with current government/ municipal drought prevention policy?	1	2	3	4	5		
	13. How satisfied are you on a scale of 1 (lowest) to 5 (highest) with current government/ municipal flood prevention policy?	1	2	3	4	5		

5. Household food insecurity (HFIAS)

This section is to understand the household food insecurity through 9 items. For each item, please answer in number of times your household has faced such a situation the last one month (30 days). If answer is 0 days = never, 1 to 2 days = rarely, 3 to 10 days = sometimes, 11 to 20 = often, greater than 20 days = always. Other options also are respondent refusing to answer to an item (refuse) and or not applicable/ don't' know (NA)

ITEM No.	ITEM/ QUESTION	RESPONSE
ITEM 1	Would not have enough food	
ITEM 2	Member were not able to eat preferred kind of food	

ITEM 3	**Eat limited variety of food**	
ITEM 4	**Eat some food that you did not want to eat**	
ITEM 5	**Eat a smaller meal size**	
ITEM 6	**Had to eat fewer meals a day**	
ITEM 7	**Eat fewer meals a day**	
ITEM 8	**Had no food of any kind**	
ITEM 9	**Went to sleep hungry**	

Appendix C: Script for household water insecurity analysis

```
*Encoding: UTF-8.
*I first used STATA to get polychoric correlation on all the
items
*The polychoric matrix obtained is as shown below as obtained
from STATA
*I then run the following command in SPSS to get my polychoric
matrix into SPSS

MATRIX DATA VARIABLES = I1 I3 I4 I5 I6 I7 I8 I13 I16 I17 I19
I22 I23 I24 I25 I26 I27 I28 I32 I33
/N= 123
/CONTENTS = CORR.
BEGIN DATA.
1
.73308888         1
.75702986  .82202898          1
.71839953  .84078968   .8370914          1
.69325792  .81151036   .8329476  .80378683          1
.661495  .85205785  .83450579   .8897617  .84966075          1
.68166006  .87178021  .85160042  .89607321   .8614397
.95415881         1
.53466433  .69255451  .67832082  .65251941  .67871619
.67858514  .73607523          1
.44493984  .35751975  .51474546  .36702718  .43589927
.40464658  .42138294   .4337411          1
.60550466  .56439007  .60589625  .61383564  .58314226
.58250925  .57422294  .56605194  .64997039          1
.37733282  .52442438  .49979327  .39541316  .50882228
.46280574  .45674474  .50562489  .40943811  .40541567
1
.48177018  .47857649  .59884318  .58938352  .57236159
.51329069  .53907929   .4126784  .60131246  .46304735
.44387268         1
.7359131  .78062939  .78970443  .77419576  .72787569
.74580566  .77163267  .66422497  .39674728  .56397327
.55296429  .54605676          1
.55756959  .77132736  .66626462  .70565564   .6706827
.7018144   .7148212  .61902826  .67058753  .64911041
.5902979  .48264421  .63180975          1
.58606513  .71578471  .72896342  .72884556  .74025424
.69846387  .72146654  .50974921   .4217259  .49366718
.37713004  .56101349  .66050795  .52842557          1
.32373518  .48447706  .45176675  .37116667  .50381088
.46781049  .45807745  .33612352  .24296437  .18819105
.45989943  .39075776  .37621909  .44720274  .32091965
1
.47393203  .70199483  .65076272  .61704393  .73147671
.65726575  .68927587  .51093732  .36536657  .47202347
```

```
.47154869  .50270173  .58948782  .59149369  .50281941
.79373019          1
.45822932  .65476792  .73722183  .64875053  .77686709
.72200897  .70514417  .52219825   .4636834  .57972386
.50180573  .5571503  .65015791  .62965181  .60021703
.56888441  .80841612          1
.59784686  .70237167  .69352874  .67505276  .74434287
.74554797  .74001807  .53848031  .33284385  .54220394
.38847608  .46278155  .64959481  .57254347  .48384359
.6767089  .85289209  .74471608          1
.61488788  .74108977  .73291484  .71167816  .70432001
.74670901  .76866674  .55634838  .29825053  .42042633
.43427431  .43714303  .71626616  .64892061  .69426005
.58412797  .63801574  .65480627  .65636108          1
END DATA.
EXECUTE.

*Then i use following syntax for a PCA with varimax rotation
to obtain my eigen values and rotated factor loadings

FACTOR
/MATRIX = IN (COR = *)
/PRINT INITIAL DET KMO REPR EXTRACTION ROTATION FSCORE
UNIVARIATE
/PLOT EIGEN
/FORMAT SORT
/CRITERIA MINEIGEN(1) ITERATE(25)
/EXTRACTION PC
/CRITERIA ITERATE(25) DELTA(0)
/ROTATION VARIMAX
/METHOD=CORRELATION.
```

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.799
Bartlett's Test of Sphericity	Approx. Chi-Square	2978.160
	df	190
	Sig.	.000

Component Transformation Matrix

Component	1	2	3
1	.765	.468	.442
2	.172	-.810	.560
3	-.620	.353	.700

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Appendix D: Choice modelling survey

Willingness to pay survey through choice cards

Please show which pair would you select, if you had to choose only one option (e.g. either Option 1 or Option 2) amongst each pair:

PAIR 1

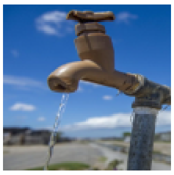
Attribute	Option 1	Option 2
Water Quantity (Increased amount in litres/ day)	180	90
Water Quality (treated/ untreated source in standpipe supply)	Treated quality	Current quality
Water Frequency (increased number of hours/ days of supply)	12	12
Price (amount to be paid in Rands/ month)	10	0

PAIR 2

Attribute	Option 1	Option 2
Water Quantity (Increased amount in litres/ day)	90	360
Water Quality (treated/ untreated source in standpipe supply)	Treated quality	Current quality
Water Frequency (increased number of hours/ days of supply)	12	Current frequency
Price (amount to be paid in Rands/ month)	50	10

PAIR 3

Attribute	Option 1	Option 2
Water Quantity (Increased amount in litres/ day)	90	180
Water Quality (treated/ untreated source in standpipe supply)	Current quality	Current quality
Water Frequency (increased number of hours/ days of supply)	Current frequency	24
Price (amount to be paid in Rands/ month)	100	0



PAIR 4

Attribute	Option 1	Option 2
Water Quantity (Increased amount in litres/ day)	360	90
Water Quality (treated/ untreated source in standpipe supply)	Current quality	Current quality
Water Frequency (increased number of hours/ days of supply)	12	24
Price (amount to be paid in Rands/ month)	50	0

Script for choice card making in SPSS

```
*generate all columns in SPSS
*use orthogonal projection and input all attribute and levels
as required
*use following syntax to run the orthogonal projection
DATASET ACTIVATE DataSet1.
GET
  FILE='C:\Users\sauna\Desktop\iwmi\Analysis\WTP2_withsp.sav'.
DATASET NAME DataSet8 WINDOW=FRONT.
PLANCARDS
  /FACTORS=quantity quality frequency price
  /FORMAT BOTH

*run the analysis
*import the saved file and open the generated choice cards
```

Notes

Output Created		27-Jul-2019 17:15:11
Comments		
Input	Data	C:\Users\sauna\Desktop\iwmi\Analysis\WTP2_withsp.sav
	Active Dataset	DataSet8
	File Label	Orthoplan output
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	25
Missing Value Handling	Definition of Missing	Missing values are not recognized as missing and are treated like other values.
	Cases Used	All cases are used.
Syntax		PLANCARDS /FACTORS=quantity quality frequency price /FORMAT BOTH.
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.07

Card List

	Card ID	quantity of water	quality of water	frequency of water	price
1	1	6*30 litres	treated quality	12 hours	10 R/month
2	2	3* 30 litres	treated quality	12 hours	50 R/month
3	3	>12*30 litres	current quality	12 hours	50 R/month
4	4	>12*30 litres	current quality	current frequency	10 R/month
5	5	3* 30 litres	current quality	current frequency	10 R/month
6	6	3* 30 litres	current quality	current frequency	100 R/month
7	7	3* 30 litres	current quality	12 hours	0 R/month
8	8	6*30 litres	treated quality	current frequency	0 R/month
9	9	3* 30 litres	current quality	24 hours	0 R/month
10	10	12*30 litres	treated quality	current frequency	0 R/month
11	11	12*30 litres	current quality	current frequency	50 R/month
12	12	>12*30 litres	current quality	12 hours	0 R/month
13	13	6*30 litres	current quality	24 hours	0 R/month
14	14	12*30 litres	current quality	24 hours	10 R/month
15	15	3* 30 litres	current quality	current frequency	0 R/month
16	16	12*30 litres	current quality	12 hours	100 R/month
17	17	>12*30 litres	treated quality	24 hours	100 R/month
18	18	6*30 litres	current quality	current frequency	50 R/month
19	19	3* 30 litres	treated quality	24 hours	50 R/month
20	20	12*30 litres	treated quality	12 hours	0 R/month
21	21	3* 30 litres	current quality	12 hours	0 R/month
22	22	>12*30 litres	treated quality	current frequency	0 R/month
23	23	3* 30 litres	treated quality	12 hours	10 R/month
24	24	3* 30 litres	treated quality	current frequency	100 R/month
25	25	6*30 litres	current quality	12 hours	100 R/month

Appendix E: Script for WTP analysis (conditional logit model)

```
*to run conditional logit via survival analysis for surface
water dependent community.

DATASET CLOSE DataSet5.
COMPUTE ftime=1+(status=0).
VARIABLE LABELS  ftime 'COMPUTE ftime=1+(status=0)'.
EXECUTE.
COXREG ftime
  /STATUS=status(1)
  /STRATA=strata
  /METHOD=ENTER quantity quality frequency price
  /PRINT=CI(95)
  /CRITERIA=PIN(.05) POUT(.10) ITERATE(20).

Case Processing Summary
          N    Percent
Cases available in analysis   Eventa    56   50.0%
     Censored  56   50.0%
     Total     112  100.0%
Cases dropped  Cases with missing values     0    0.0%
     Cases with negative time 0    0.0%
     Censored cases before the earliest event in a stratum  0
     0.0%
     Total     0    0.0%
Total          112  100.0%
a Dependent Variable: COMPUTE ftime=1+(status=0)

Omnibus Tests of Model Coefficients

-2 Log Likelihood   Overall (score)               Change From
Previous Step            Change From Previous Block
     Chi-square     df   Sig. Chi-square     df   Sig. Chi-
square    df   Sig.
59.583    15.908    4    .003 18.050    4    .001 18.050    4
     .001
Beginning Block Number 1. Method = Enter


*to run conditional logit via survival analysis for
groundwater dependent community.

DATASET CLOSE DataSet6.
COMPUTE ftime=1+(status=0).
VARIABLE LABELS  ftime 'COMPUTE ftime=1+(status=0)'.
EXECUTE.
COXREG ftime
  /STATUS=status(1)
```

```
  /STRATA=strata
  /METHOD=ENTER quantity quality frequency price
  /PRINT=CI(95)
  /CRITERIA=PIN(.05) POUT(.10) ITERATE(20).
```

Case Processing Summary
N Percent
Cases available in analysis Eventa 128 50.0%
Censored 128 50.0%
Total 256 100.0%
Cases dropped Cases with missing values 0 0.0%
Cases with negative time 0 0.0%
Censored cases before the earliest event in a stratum 0 0.0%
Total 0 0.0%
Total 256 100.0%
a Dependent Variable: COMPUTE ftime=1+(status=0)

Omnibus Tests of Model Coefficientsa

-2 Log Likelihood Overall (score) Change from Previous Step Change from Previous Block
Chi-square df Sig. Chi-square df Sig. Chi-square df Sig.
163.725 13.166 4 .010 13.720 4 .008 13.720 4 .008
a Beginning Block Number 1. Method = Enter