Dissection of the Western Cape Drought focusing on the Response and Adaptive Capacity of Langa, Cape Town

Report to the

WATER RESEARCH COMMISSION

by

MS Muthige, NS Kobo, LE Mpheshea, R Nkoana and E Moyo

CSIR Smart Places

WRC Report No. 2940/1/20

ISBN 978-0-6392-0192-4

October 2020

Obtainable from
Water Research Commission
Private Bag X03
GEZINA, 0031

orders@wrc.org.za or download from www.wrc.org.za

EXECUTIVE SUMMARY

Climate change and variability have led to challenges concerning water supply and droughts. This has been attributed to global warming and an increase in greenhouse gas emissions. As a result, there has been a significant increase in surface temperature leading to extreme weather events such as droughts. Urbanization and population growth have impacted on existing water supplies and with current model projections showing a significant increase in temperatures and probability of more droughts and drier conditions, it is essential for cities and urban population to adapt to supply and demand-side planning as well as existing infrastructure to accommodate potential future threats.

Cape Town, a swiftly urbanizing city of the Western Cape Province, became acutely aware of the new water challenge in 2017, after a three-year drought which resulted in the six large reservoirs which supply water to the ~3.7 million residents had insufficient water to meet the demand. The livid experiences of the City of Cape Town residents, through the 2015-2017 drought popularly called day zero are an important learning lesson for most cities globally, specifically those which have fast-growing urbanization and large socioeconomic disparity.

This project objectives included simulating present-day stream flows and river water depth in the Western Cape Water Supply Region and to understand the impacts of climate variability on streamflow and water reservoirs. It also explored how drought policies, reforms, and paradigms changed over time. Through a case study approach, the nature of the relationship that subsisted between residents of Langa Township and its informal settlement in Cape Town during the 2015/17 drought period with the focus on the communication process, efforts made by citizens and the recommendations recommended by the citizens on how to manage drought effectively including the role of some of the actors and institutional arrangements were explored.

Analysis of the drought policies reform and changes overtime was done through an extensive literature search. The effects on climate change and variability on dam levels were established through accessing the database of the city of Cape Town. Present-day streamflow and river water depth were modelled using the Conformal Cubic Atmospheric Model. A questionnaire was administered to the residents of Langa Township and Informal settlement to understand how the drought-impacted water supply and their coping mechanism and any

recommendation they have for the city of Cape Town when it comes to the future water supply when there is a drought.

The project has shown that there has been a significant decline over the three years (2015-2017) when it comes to the storage level within the six major reservoirs in Cape Town. This was associated with below-normal rainfall which Cape Town had experienced. The study has also shown that changes in public drought policies in South Africa have not been characterized by rapid shifts, but rather by consistency and robustness in ways that the government, scientists, societies and technical personnel has executed policy solutions to drought problems in South Africa. From the case study approach, the study has unearthed the coping or survival strategies that the residents of the marginalized Township and informal settlement of Langa implemented to reduce the dreading impacts of the drought.

ACKNOWLEDGMENTS

The authors would like to thank the Reference Group of the WRC Project for the assistance and the constructive discussions during the duration of the project:

Dr Brilliant Petja	Water Research Commission
Dr Mary-Jane Bopape	South African Weather Services
Dr Babatunde Abiodun	University of Cape Town
Mr Robert Maisha	South African Weather Services
Dr Christien Engelbrecht	South African Weather Services
Mr Steven Phakula	South African Weather Services
Dr Rakhee Lakhraj-Govender	Tshwane University of Technology

This page was intentionally left blank

TABLE OF CONTENTS

LIST OF FIGURES

This page was intentionally left blank

1 INTRODUCTION

1.1 Contextual Background on the three-year Drought

The last half the decade has witnessed the occurrence of several remarkably intense and high-impact weather events in Africa and the rest of the world. The summer of 2015/16 was associated with the most intense El Niño event ever recorded. The year 2015 also turned out to be the warmest calendar year in recorded history, only to be superseded in this regard by 2016 and 2019. Moreover, in 2015 a critical symbolic (and physical) threshold was exceeded – it was the first year for which the global average surface temperature was 1°C warmer than the pre-industrial average. This period of unprecedented global temperatures is thought to have been the result of systematic global warming under the enhanced greenhouse effect in combination with natural variability in the form of an intense El Niño event.

Also in southern Africa the impacts of the 2015/16 El Niño event were significant. The region experienced its warmest summer period in recorded history, in the order of 2°C warmer than the present-day average climatological temperature. In fact, during this period numerous weather stations in the southern African interior recorded average monthly temperatures in the order of 5°C above their monthly average climatological temperatures. Water restrictions followed over much of South Africa and the maize crop yield was reduced significantly. Over much of the summer rainfall region of southern Africa, the La Niña event of 2016/17 brought significant relief of the oppressive temperatures and drought.

However, in 2017 South Africa became acutely aware of a new water crisis, this time in the winter rainfall region. It should be noted that from the period 2015 until 2017 the winter rainfall region of South Africa (Cape Town) received below normal rainfall. All those three years were considered to be drought years of increasing severity – with 2017 being the driest year recorded by several rain gauges (Otto et al., 2019; Taing et al., 2019). Some relief was only gained during the June winter rainfall in 2018 (Burls et al., 2019).

Furthermore, the three-year deficit in rainfall, an event that is extremely rare with a probability of occurring in ~ 150 years resulted in distress within the entire Western Cape Province. In Cape Town, the six large reservoirs which supply water to the ~3.7 million residents had insufficient water to meet the demand (Otto et al., 2019).

Such a crisis brought enormous pressure on water demand and allocation in the city of Cape Town, with dams that supply the residents with water dropping to approximately 21% Capacity in May 2018 (City of Cape Town, 2018; Simpkins, 2018; Wolski, 2018).

1.2 Interventions made to manage the three-year drought

During the month of January 2018, the city of Cape Town was on a third consecutive year of drought and it was experiencing a real threat of running out of the water (Ziervogel, 2018). In response to the drought, the city of Cape Town gradually took certain measures to reduce water demand and use. This section reviews some of the response and management measures that were put in place in response to the 3-year consecutive drought. It will look at both the technical and institutional responses. To deal with the water crisis, the city of Cape Town decided to prioritize managing water demand and supply, and below are some of the measures taken to deal with the crisis.

Water restrictions

The City of Cape Town introduced increasingly strict water restriction which evolved as the water crisis intensified (Matikinca et al., 2020). The highest level of restriction was introduced in February 2018, which is level 6B. Within Level 6B, residents were limited to a maximum of 50 litres of water per person per day. The restrictions were revised on ad hoc basis by the city of Cape Town and at that time their city was under the state of emergency laws, meaning that the decisions to increase or reduce the restrictions may have been done in an autocratic manner. The restriction came with limitations on which water use practices can be applied, e.g. gardening, outdoor pools, and washing cars was prohibited (Matikinca et al., 2020).

Tariff increment

In response to the drought, the water tariffs in Cape Town were increased drastically between 2016 and the late stage of 2018. They only got reduced after October 2018 (City of Cape Town, 2018). The new tariff system which was introduced during the drought was targeted at charging more for the users who consume more volumes of water (Matikinca et al., 2020). During the drought, all free basic water provisions for the citizens were removed for all the non-indigent households.

Water pressure reductions

From the year 2017, the city of Cape Town decided to reduce the water pressure in all its municipal pipes. The reduced water pressure resulted in great water-saving benefits, i.e. the frequency of leakages and burst pipes was greatly reduced.

Public Campaigns to encourage water savings

From 2016 the city of Cape Town initiated several water-saving campaigns. Adverts were made on several platforms such as billboards, social media, and radio to assists and spread the message of encouragement to the residents for them to save water. A website was created dedicated to displaying dam levels and consumption levels to aid the citizens to understand their water usage and availability.

1.3 Objectives of the project

This study aims to explore 2015-2017 below normal rainfall and the calamity of the 2015/16 drought on the water supply and demand of Cape Town, with a case study focussed on Langa Township and informal settlement. The specific objectives of the project are stipulated below.

- to simulate present-day stream flows and river water depth in the Western Cape Water Supply Region
- To understand the impacts of climate variability on streamflow and water reservoirs
- To explore how drought policies have changed over time
- To explore the disparities between different residential settings in times of drought
- To evaluate the preparedness and response of the community during the 2015/16 drought

1.4 Outline of the document

The document follows the following structure:

Chapter 2 explores drought policies in South Africa through time and how they have changed

Chapter 3 gives the methodological Approach into the study

Chapter 4 provides a summary of the climate of the Western Cape Province and how it affects water availability.

Chapter 5 gives a background on Langa and how drought affected its residents

Chapter 6 gives concluding remarks for the project

Thereafter references are provided, as well as some appendices with details from the research

2 EVOLUTION OF PARADIGMS AND DROUGHT POLICIES IN SOUTH AFRICA: A JOURNEY THROUGH TIME

2.1 Introduction

The vulnerability of Africa to climate change and variability including periods of drought is well documented and acknowledged by policymakers, farmers, and natural resource managers (Vogel et al., 2009, Boko et al., 2007). Drought is an insidious phenomenon that characterizes climates in virtually all parts of the world (Wilhite and Buchanan-Smith, 2005). It is estimated that about one-third of African communities live in drought-prone areas. Historically, droughts have been associated with feminine, mortality, agricultural loss, and economic setbacks in most countries in Sub Saharan Africa. For example, the 1992 drought in southern Africa affected about 20 million people and resulted in a deficit of more than 6.7 million tons of cereal supply in the region (SADCC, 1992). Globally, a need for scientists to play a significant role in policy development and drought management has been identified (O' Meagher et al., 1998). Scientists have stressed the importance of scientific input into political decision making to improve drought management practices and policy development. For instance, in Australia, Howden et al. (2014) observed that the scientific input into drought management had resulted in the sciences shifting from focus on climate data to people, communities, and integration of biophysical science with economics for sound policy development.

This chapter focuses on issues of drought, particularly examining the evolution of public policies and paradigms since the year 1800s in South Africa. The chapter also provides an analysis of drought trends since the 1800s and a summary of ideas, paradigm shift policy, and drought management in South Africa.

2.2 Drought as a natural hazard

One can define drought as a period of drier than normal conditions that result in water-related problems (Dai, 2011). South Africa is a semi-arid country which is vulnerable to drought. The primary input to water resources is rainwater and the country receives an average of about 490 mm rainfall per year (Hassan, 2013) which is below the world's 860 mm average per year (Botai et al., 2018). Most of the rainfall in South Africa occurs mainly during the summer season although in the southwestern region rainfall occurs mostly in the winter season. A natural factor of not receiving rainfall over time can cause a drought. Unnatural factors including the use of too much or misuse of water during times of normal rainfall, may result in less water being available during the occurrence of the drought event (Wilhite et al., 2014).

2.3 Types of drought

Drought has many characteristics and it always starts with a deficiency in precipitation affecting soil moisture, streamflow, groundwater, ecosystems, and humans depending on the duration and intensity of the drought (Smakhtin and Hughes, 2004). Drought can then be classified into four categories viz. meteorological, agricultural, hydrological, and socio-economic.

Meteorological drought is mainly defined by the "deficiency of precipitation from expected or normal amount over an extended period" (UNISDR, 2003:4). This type of drought focusses on the physical characteristics of drought, such as the departure of rainfall from normal, rather than the impact of the drought itself. It depends also on the normal climatic conditions of an area, hence a definition developed in one region needs to be modified before it is applied in another region (Sun, 2009).

Agricultural drought occurs when there is a deficiency in soil moisture which affects crop yields, pasture yields, and livestock holdings. (Wilhite, 1997; Bordi and Sutera, 2007). This type of drought usually occurs when plant water demand cannot be met due to hydrological or meteorological drought. It is worth noting that agricultural drought does not only depend on the amount of precipitation received but also the timing and duration of the drought (Fraisse et al., 2011). Agricultural drought is also linked to several characteristics of meteorology such as deficient precipitation, high evapotranspiration leading to soil water deficits, resulting in the impact of agricultural processes (Das, 2012)

Hydrological drought – is associated with reduced runoff and shortage of streamflow and groundwater (Tallaksen and van Lanen, 2004). It normally occurs after prolonged meteorological and agricultural drought, due to the time lag between rainfall deficiencies and hydrological system elements (Sun, 2009). This type of drought is normally exacerbated by the rate of water loss through factors such as evapotranspiration and other social activities such as water abstraction from the ground.

Socioeconomic drought occurs when the deficit in rainfall starts to affect human wellbeing, health, and quality of life (Sun, 2009). This is due to the reliance on livestock grazing and grain produce on rainfall (Sun, 2009). It relates to the impact of meteorological, Agricultural, and Hydrological drought on the vulnerability of human beings (Wilhite and Buchanan-Smith, 2005).

2.4 Impacts of drought as a hazard

The impacts of drought are complex and dynamic in nature (Vogel, 1994, Wilhite et al., 2007). It is difficult to quantify the impacts of drought since they are non-structural, hence they can be classified as environmental, economic, and social (Heim, 2002). Drought impact does depend on the intensity and duration (Rouailt and Richard, 2005), however, it should be noted that a drought of similar intensity can have different impacts at different times over different areas (Wilhite et al., 2007). The impact of drought also depends on vulnerability and social inequalities and varies with the coping mechanism in place and the ability to build resilience (Dai, 2011b). For example, in countries with developing economies heavily relying on agriculture, drought can trigger severe famine and loss of human lives (Hayes et al., 2012).

2.4.1 Environmental Impacts

The impact of drought on the environment varies as there are those which last long after drought has passed and there are other which can be rehabilitated at a shorter space of time. An intense drought can result in land degradation that may harm agricultural land productivity (Vogel et al., 2000). Drought may also negatively affect surface and underground water resources (Vogel, 1994; 2000), e.g. during the 1991/92 drought in southern Africa, approximately 90% of small dams dried up in Botswana, Namibia, South Africa and Zimbabwe (Jury and Mwafulirwa, 2002).

2.4.2 Social impacts

Often drought results in low crop production or yield and high levels of water shortage. This increases food prices and a high unemployment rate which has a direct negative impact on the community (Vogel et al., 2005). The impact of drought on a community may take a longer time than expected, it may go on even if the incident has stopped, resulting in food insecurity (Vogel et al., 2000). Drought can negatively change the livelihoods of the communities which mainly rely on natural environments such as water and food production.

2.4.3 Economic impacts

The economic impacts of drought are divided into direct effect, indirect effect, and the induced effect (e.g. Hayes and Widhalm, 2013; Diersen and Taylor, 2003). The direct impact of drought relates to the physical water deficiencies on production, e.g. in southern Africa Maize yields were significantly reduced during the droughts of the 1980s, with a deficit of 10% of normal during 1982-1984(Vogel, 2000; Makarau, 1994). In the case of the agricultural sector, the indirect effects would be the effects on the upstream and downstream businesses such as agro-processors and supply chain. Then the induced effects will affect the consumers and businesses on the upstream.

2.5 The early drought adversity before policy formation

The first recorded narrative of drought in South Africa was in the nineteenth century in South Africa. It was during the early 1800s between 1801 and 1830 that the impacts of drought were felt, specifically in the Cape Colonies (Ballard, 1986). Historical records show that such period had recurring and prolonged periods and from the observation of the early 1820s settlers it is said to have been three consecutive years of drought between 1821 and 1823. Such a period of prolonged drought had a significant impact on the day to day activities of the settlers and they decided to foster new ways of becoming self-sufficient such as trading, hunting, and commerce (Ballard, 1986). It should be noted that the area affected by drought was not only the Cape Town but also the Eastern Cape, Northern Cape, KwaZulu-Natal, and the then Transkei and Ciskei.

2.6 Post-Apartheid period (Early Democracy Period).

During the early 1990s, South Africa, was going through a political reformation. The country was going through a major political dispensation, changing from the apartheid led policies (Holloway, 2000). The drought in 1992-93 was regarded as the most severe drought to ever occur in South Africa at that time (Vogel and Drummond, 1993), only to be surpassed by the 2015/16 drought event. The former was associated with a strong El Nino event, which resulted in below normal rainfall and drought across the entire southern African region. The drought resulted in a reduction in water supply and agricultural produce. Unfortunately, the country at that specific period did not have any early warning system in place, to enhance advanced preparation and management of drought.

The main severe impact of the 1992-93 drought was felt on food production with an increase in food imports more especially on the cereal sector, wherein South Africa saw a decline in its crop production by 40% (Holloway, 2000). Food security in most of the rural areas of South Africa was affected, e.g. in the then Venda homeland, just about all dryland crops failed and in the then GaZankulu former homeland nutritional reported to have increased threefold.

2.7 Evolution of drought relief programs in South Africa

South Africa has had a long history of involvement in providing relief to white commercial farmers, however, such relief was only for a period when there is a drought (Vogel, 1994c, Vogel et al., 2000 and National Department of Agriculture, 2005). The first intervention by the government was the 1914 Drought investigation commission which recognized soil erosion as a crucial factor worsening the impact of drought (Dodson, 2003). The commission recommended the conservation of soil and the improvement of water management. In the 1960s further drought relief plans were made to address the challenge of drought and soil conservation (Vogel, 1994a). This time around it was the formation of the bureau by the Drought Committee. The bureau was structured in such a way that the staff will be limited during drought and more staff will be hired during the period of drought. The bureau, however, was more focused on livestock farmers and they gave little concern to rural farmers.

After the 1980s, a new paradigm into drought relief was established, and it was named the Phase drought relief scheme. The approach that was used to provide relief was that of Transport rebates, loans, and subsidies (Bruwer, 1989). It should be noted that this kind of relief was designated for farmers that practiced conservation in their practices. Such kind of relief resulted in farmers being over-dependent on government and it was not sustainable.

2.8 Post-Apartheid era policy reforms and Drought relief

The drought of 1992/93 season occurred when South Africa was going through a change in political dispensation. The drought was severe and the drought schemes and relief processes of that time had a huge impact on the government's finances and the taxpayers. The public started bargaining for a more proactive, rational, and cost-effective way of managing drought. As a result, the National Drought forum named the National Consultative Drought Forum was established to provide emergency response to the drought (Vogel et al., 2000). It was through this forum that it was concluded that the previous drought policies had a huge deficiency in them. They never included rural farmers in their relief efforts and there were no efforts placed towards developing those farmers, the support was mainly directed towards white commercial farmers.

In 1993, priority was then shifted towards water supply systems, communication, implementation, and maintenance through this consultative process. Thus, a Drought strategy task team named the Drought Action-Coordinating Center submitted a proposal on Drought management to the National Consultative Forum.

The proposal only came to a realization in 1995, when the National Disaster Management Committee (NDMC) was established at a national level. Directives were given out to include disaster management, pre-disaster risk reduction, and an integrated disaster information system at provincial and local levels (Vogel et al., 2000).

In 1997, great strides were made in terms of disaster management in South Africa, a Green paper on disaster Management was initiated and then it became a white paper in 1999. The white paper stimulated the re-orientation of national disaster Management to focus more on prevention and mitigation rather than focusing on relief and recovery (van Zyl, 2006). The disaster Management Bill was then introduced to the National Assembly in 2001. The aim of the bill was to provide for an integrated and coordinated disaster management policy. The bill became an Act in 20002 and it was known as the National Disaster Management Act of 2002; the National disaster Risk Framework was implemented in 2005 in South Africa. This was a definitive method for coping with droughts and disasters in South Africa.

2.9 Final Remarks

This historical appraisal indicates that changes in public drought policies in South Africa have not been characterized by rapid shifts, but rather by consistency and robustness in ways that the government, scientists, societies and technical personnel has executed policy solutions to drought problems in South Africa. Public Debates surrounding drought are commonplace in the media (e.g. the 2015/17) Cape Town drought).

3 METHODOLOGY

3.1 Model simulation

The Conformal Cubic Atmospheric Model (CCAM) is applied here to generate climate simulations in the Western Cape. CCAM is a variable resolution, global atmospheric model. It was been developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia (Engelbrecht *et al*., 2009; McGregor, 2005). The CCAM is set to solve hydrostatic primitive equations applying a semi-implicit, semi-Lagrangian equations using both dynamical and physical parameterization such as Geophysical Fluid Dynamical Laboratory (GFDL) parameterization for both longwave and shortwave radiation, with interactive cloud distribution as determined by the microphysics scheme (Engelbrecht *et al*., 2011; Engelbrecht et al*.,* 2015).

The CCAM can be applied across different spatial and time scales, and as such provides an opportunity to test for the physical robustness of its numerics and physical parameterization schemes (Engelbrecht et al., 2009). The CCAM model has been previously been applied over southern Africa, and verification has found that the model is capable of realistically simulating the present-day climate over southern Africa including daily forecasts, seasonal forecasts, and extreme rainfall events (Engelbrecht and Engelbrecht, 2014).

For this study, the CCAM simulations are conducted for the period (1979-2017), where the model is set up at a quasi-uniform horizontal resolution of 50 km over the whole globe and forced with the European Centre for Medium-Range Weather Forecasting (ECMWF) Reanalysis (ERA) Interim data. The ERA-Interim data are constrained model output, with variables assimilated closer to global observations (Sillmann et al., 2013). This data includes sea-surface temperatures (SST) and sea ice (Engelbrecht et al., 2009), with data input at six hourly intervals. The model was initialized using variables including surface geopotential heights, urban fraction, soil type, vegetation type, vegetation fraction, surface roughness, leaf area index, surface temperature, sea ice, and 10m winds.

The 50 km global output model is downscaled to provide input to the 8 km centered over South Africa. A Schmidt stretched-grid mode is applied at 8 km such that better spatial resolution of enhanced grid spacing is achieved over South Africa. The 8 km output is written out every six hours.

3.2 Observations

Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) is a rainfall dataset in the domain [50° N – 50 °S; 180° W – 180 °E]. CHIRPS data has a spatial resolution of 0.5° (~5km) and spans from 1981 to near present (Funk, et al., 2015). This dataset is considered here as the true estimate of rainfall and it used to analyze the 2015/16 drought event

3.3 Population sampling

3.3.1 Research Instruments

Data for the study area was mainly gathered from the questionnaire, whereas secondary data was collected from relevant literature. Water demand data and census was obtained from the City of Cape Town portal. A total of 9 questions were administered to all the residents who were systematically randomly selected and willing to partake in the study. The questions were related to their sources of water; quality of water and during and after the drought. Another section was related to behavioural changes in water-saving and consumption as well as suggested drought management strategy for the city of Cape Town.

3.3.2. Selection of Candidates

The residents of Langa were randomly approached and were asked for permission to participate in the research. It should be noted that for the participants to be eligible to partake in the study they were supposed to be 18 years old or older. The other criteria was that the residents had to be staying in Langa between 2014 and 2020. A total of 250 Candidates participated in the study, with a total of 67 participants coming from the informal settlement.

3.3.3 Motives for the questions

The motive for the first four questions was to probe how the residents accessed their water during and after the drought and more importantly to ascertain if they were satisfied with the quality of the water they were getting (see annexure 1 for the questionnaire). This is of importance since it will allow the researchers to identify how the drought impacted the marginalized and vulnerable communities in accessing water as well as determining the quality of water during the drought. Question 6 dealt with access to information, it will give insight into how people in the township and informal settlement were informed about the drought, and who do they think is responsible for informing them about drought-related issues.

The fifth question was based on the lessons learned during the drought, i.e. if the residents are saving water currently. The question is of paramount importance since it can be useful in determining if the day Zero campaign and the wrath of the drought have changed the residents' behaviour. Going further the last two questions focussed on the Drought coping mechanism – those questions were meant to assess the preparedness of the citizens should drought occur again. The very last question serves as recommendations to the City of Cape Town on how the can implement drought management strategies and assess if the strategies that they implemented are effective in different residential settings.

3.3.4 Ethical considerations

To avoid potentially unsatisfactory practices, which could endanger the participant's confidentiality of the research participants was maintained, hence the identity of all the participants surveyed during the study is kept anonymous. All the participants were made cognizant that participation in the study was voluntary and they were free to not participate in the study.

3.3.5 Research Limitation

The study was meant to explore how the 2015/17 drought affected the communities with different socio-economic statuses. The planned study areas were Langa Township and Informal settlement and the Affluent suburb of Wynberg. Unfortunately, the surveys were planned as the global pandemic Covid-19 was becoming a threat in South Africa. The survey was planned for 5 days in the week of the 16th until the 20th of March 2020. Unfortunately on the 18th of March 2020, the President announced Covid-19 pandemic a National state of Disaster. The team decided not to continue with the surveys to protect the health of citizens, the reputation of the CSIR, and WRC, as well as to maintain the ethical nature of the research. It should be noted that the initial surveys for Wynberg were planned for the afternoon of the 18th-20th March 2020. Hence, this research does not contain results for Wynberg Suburb.

4 THE CLIMATE OF THE WESTERN CAPE PROVINCE

4.1 Climate and water supply in the Western Cape Province

The Western Cape Province is situated in the southernmost part of South Africa. It is surrounded by the Warm Indian Ocean and the Cold Atlantic Ocean. Unlike the rest of South Africa which has a subtropical to a tropical climate, the province is characterized by Mediterranean Climate receiving most of its rainfall in austral winter. On average it receives an annual rainfall of ~ 350 mm which is way below the country's annual average of 500 mm (Dennis and Dennis, 2012). The main rainfall bearing systems that supply rainfall to the province are the Cold fronts embedded within extra-tropical cyclones and upper air systems including cut off lows and troughs. The austral summers in the province are however dry with temperatures ranging from 15-27°C (Kruger, 2004; Naik and Abiodun, 2019).

4.2 Climate variability and water security in the Western Cape

South Africa receives most of its rainfall during austral summer with an exception southwestern Cape region which comprises of the Western Cape and Northern Cape Provinces. The June-August (JJA) are typical austral winter months. During this season the frontal systems extend further northwards and their passage tends to be more frequent over the southwestern Cape bringing rainfall into the region. As depicted in Fig. 1, the spatial coverage of measured rainfall exceeding 100 mm/month over Western Cape tends to be larger during June, July and August compared to the rest of the months. Figure 2 illustrates the average seasonal river water depth for all the four seasons. Similarly, since River depth (a proxy of streamflow) is a primary result of rainfall; CCAM simulated maximum river water depth during the JJA period (see Figure 2). Major rivers in Western Cape such as the Berg River, Olifants River, and Breede River tend to be well defined during the JJA and SON periods.

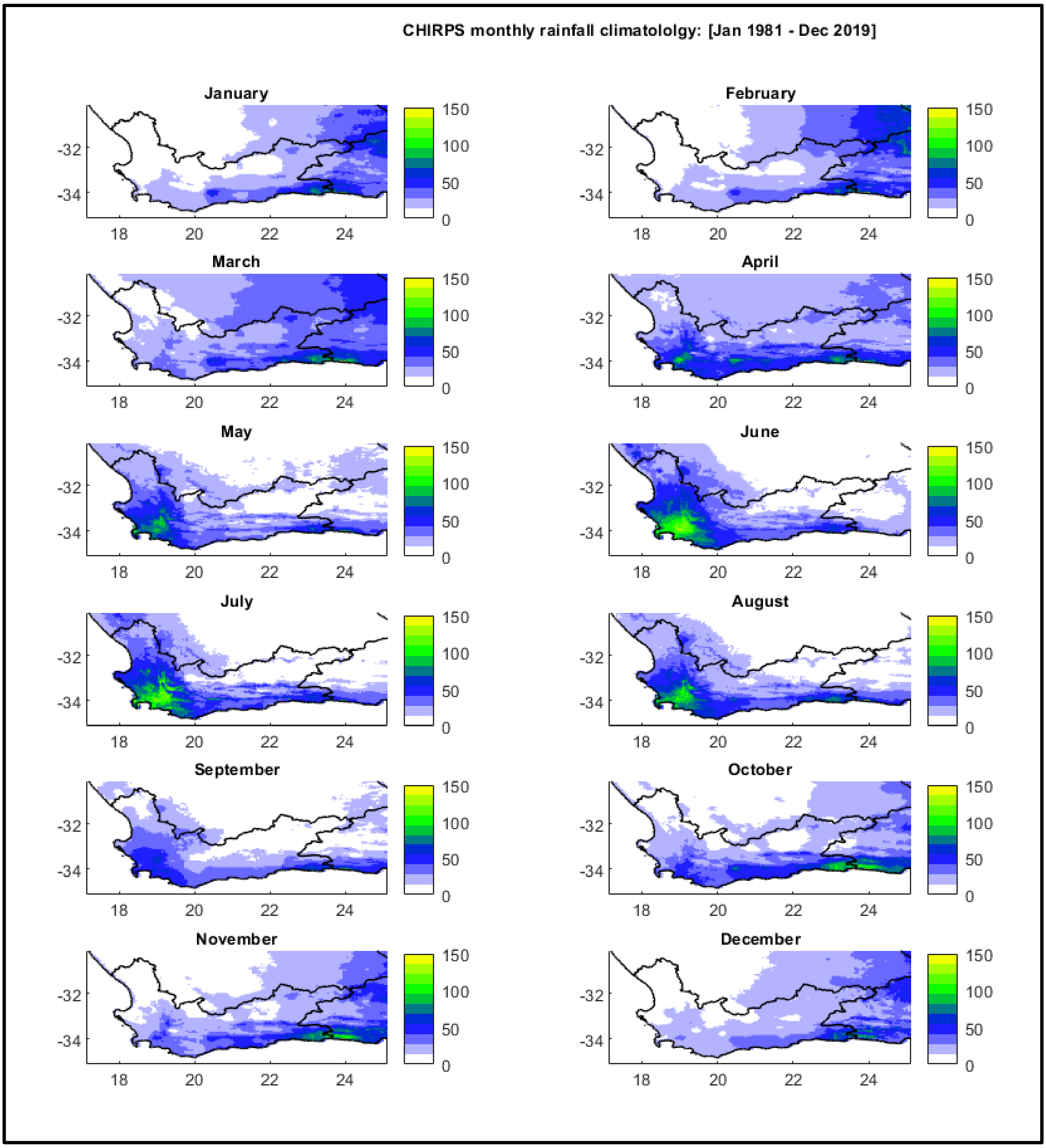

Figure 1: mean monthly rainfall computed over 39 years [from 1981 to 2019].

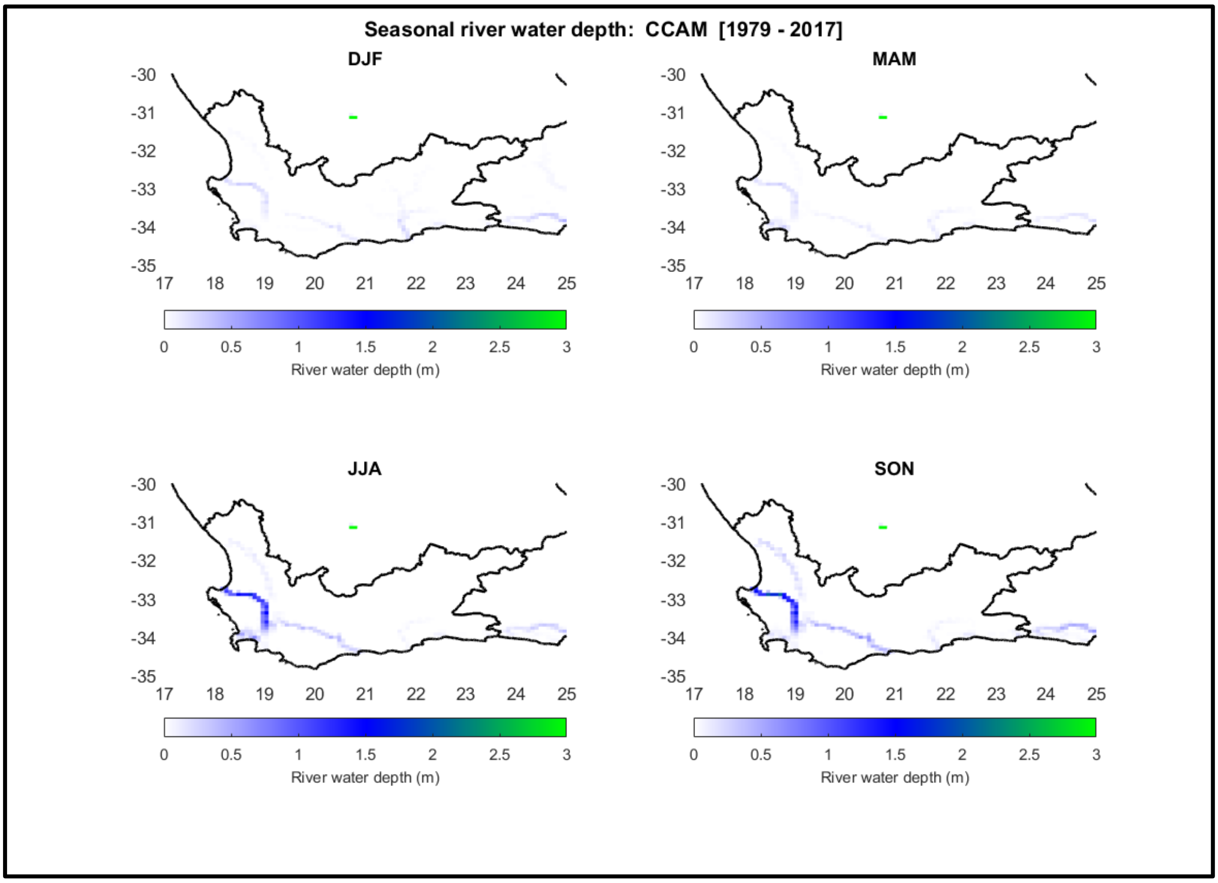

Figure 2: Seasonal average river water depth (a proxy for streamflow) as simulated by CCAM.

The results shown in thus far suggest that the onset and cessation of rainfall season in the Western Cape occurs in May and August respectively. It is during this period (May-August); that the dams in the region become significantly replenished. This implies that if dry climatic conditions persist in this period, availability of surface water and water supply would be affected negatively. The 2015/16 drought event highlighted the extent to which climatic process can have an impact on water supply. For instance, the case of City of Cape Town where during this drought water restrictions had to be imposed on the community, industries as well as local businesses. Less or no rainfall combined with hot temperatures is unfavorable configuration for water storage. The Western Cape Water Supply System (WCWSS) which serves the City of Cape Town and the surrounding small towns is made up of a network of rivers and dams of six of them namely: Voëlvlei; Wemmershoek; Berg River; Steenbras Upper; Steenbras Lower and Theewaterskloof Dam – when put together these dams contribute about 99.6% to the supply system. Figure 6 shows the monthly long-term mean water levels in the six major dams computed for the hydrological years spanning from 2007/08 to 2018/19. Across all dams there seems to be a similar pattern wherein peak water levels are seen in October and gradually decreasing towards austral winter season. The lowest water levels tend to occur around April and May. In June, the water levels starts to gradually increase towards the summer period (See Fig 3). The results shown in Fig 1 and Fig 3, taken together, indicate a month-lag relationship between rainfall and dam levels in the Western Cape. In order to examine impact of the evolution of the how the 2015/2016 drought on water supply, the observed dam levels for 2015, 2016 and 2017 hydrological years were superimposed over the long-term mean and are presented in Fig 3. The results show that Voëlvlei Dam; Wemmershoek Dam and Berg River Dam recorded dam levels close to or above the long-term mean for the hydrological years between 2015 and 2017 (see Fig 3a-c). Theewaterskloof Dam; Steenbras Upper and Lower Dam recorded below the long-term mean for the considered years. Steenbras Upper and Lower Dams both recorded levels low enough to the point where water could not be abstracted from the dams (as depicted in Fig 3).

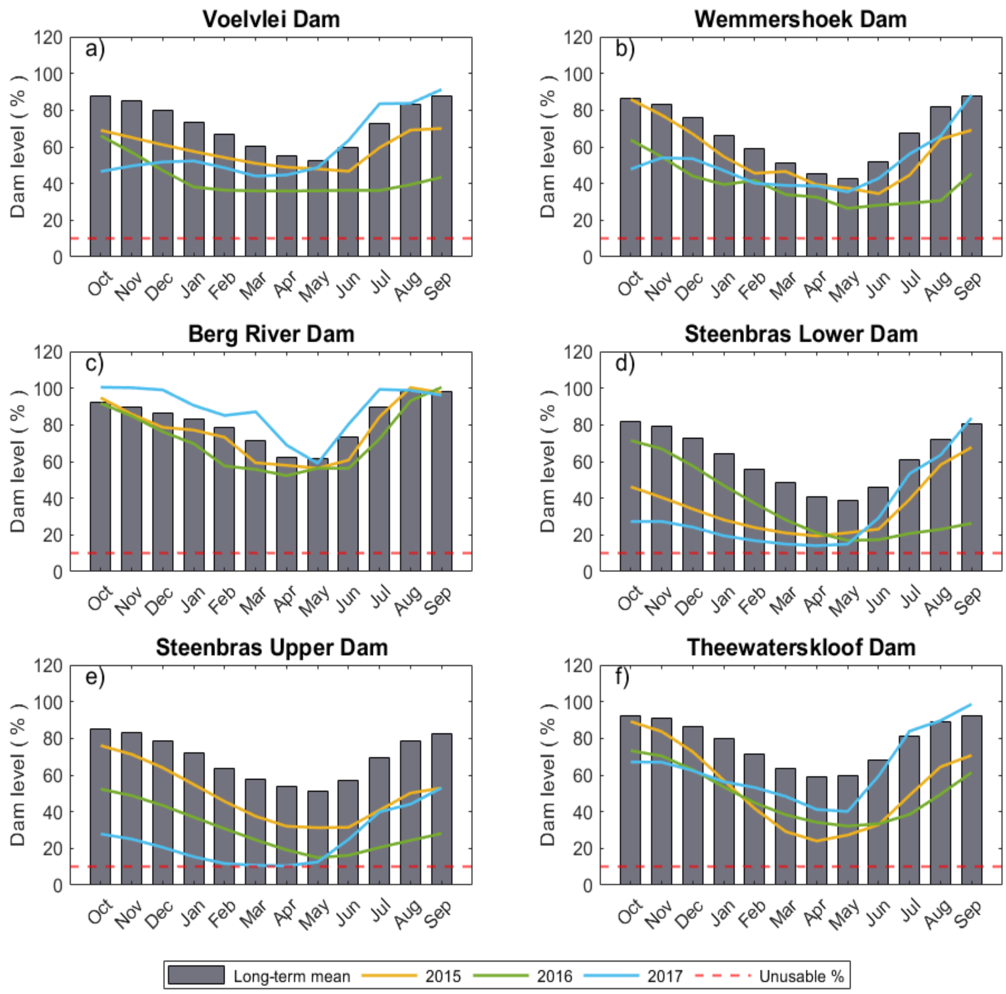

Figure 3: Long-term mean of dam levels of the WCWSS and 2015. 2016 and 2017 observed levels. The dashed red line indicates the unusable dam level percentage.

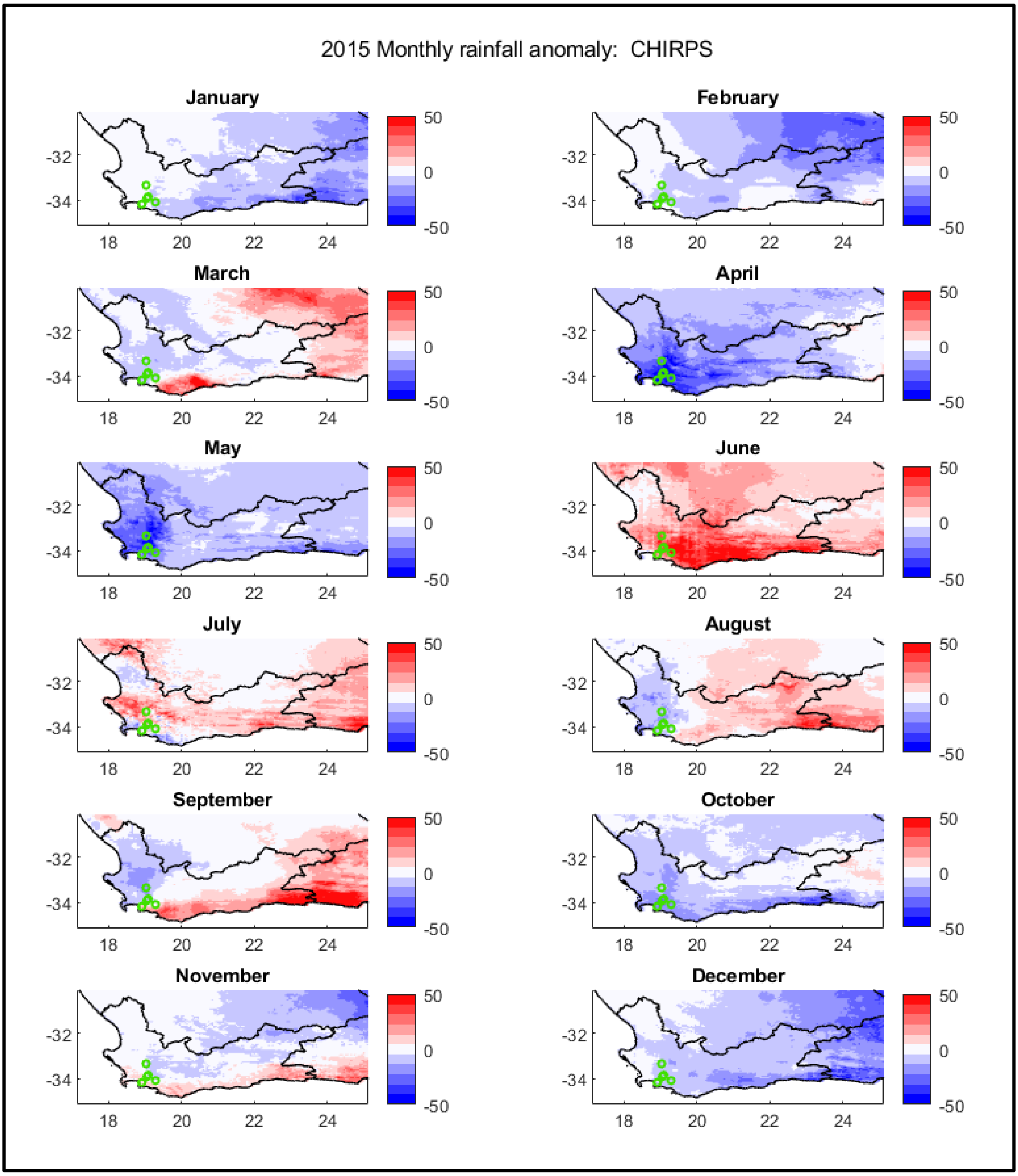

Figure 4: Observed monthly rainfall anomaly for 2015. The location of WCWSS dams are indicated by green circles

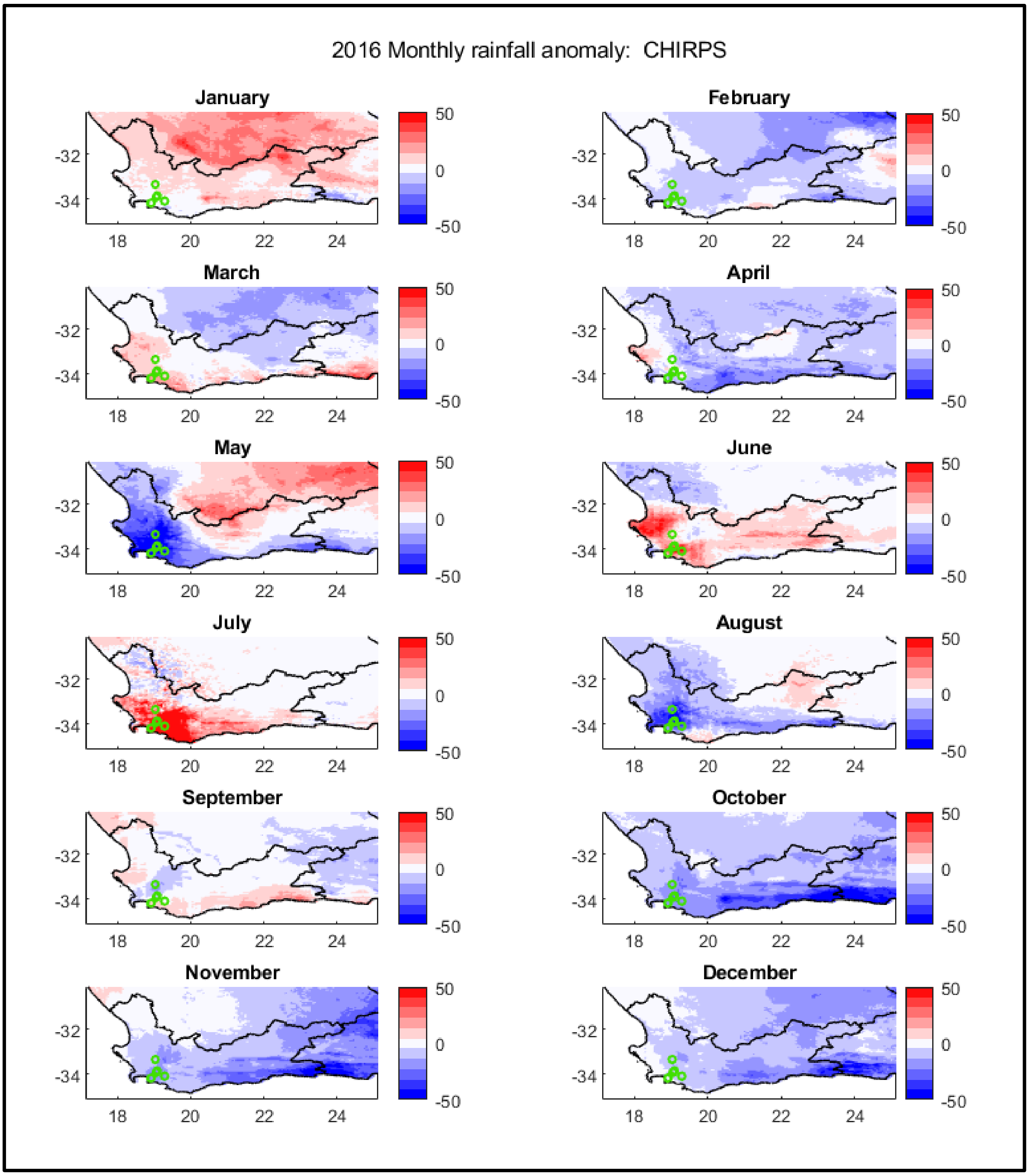

Figure 5: Observed monthly rainfall anomaly for 2016. The location of WCWSS dams are indicated by green circles

The monthly rainfall anomalies for the three consecutive years starting from 2015 were computed to track the deficit rainfall during the evolution of the 2015/2016 drought event. The results are shown in Figures 4-6. In 2015, from January to May, the majority of the Western Cape recorded rainfall less that climatological mean with May recording the highest deficit in the order of 50 mm/month (See fig 4). The month of May, as shown in Figure 1, tends to mark the beginning of the rainy season however during that year the season appears to be been delayed. Around June 2015, the recorded rainfall amounts exceeded the climatology.

This rainfall surplus only lasted for one month as more part of the Western Cape received lesser than normal rainfall in July and in August the drier conditions seemed to intensify and spread widely. Going into 2016 (see fig 5), during March and April the Western Cape recorded more rainfall compared to their respective climatological means. For May, lesser rainfall than normal was measured. June and July above normal rainfall conditions were observed although not as intense as what was recorded in the previous year. Figure 6 shows that winter season [June-July-August] on 2017 was the driest of the three years as during all these months less than normal rainfall was recorded.

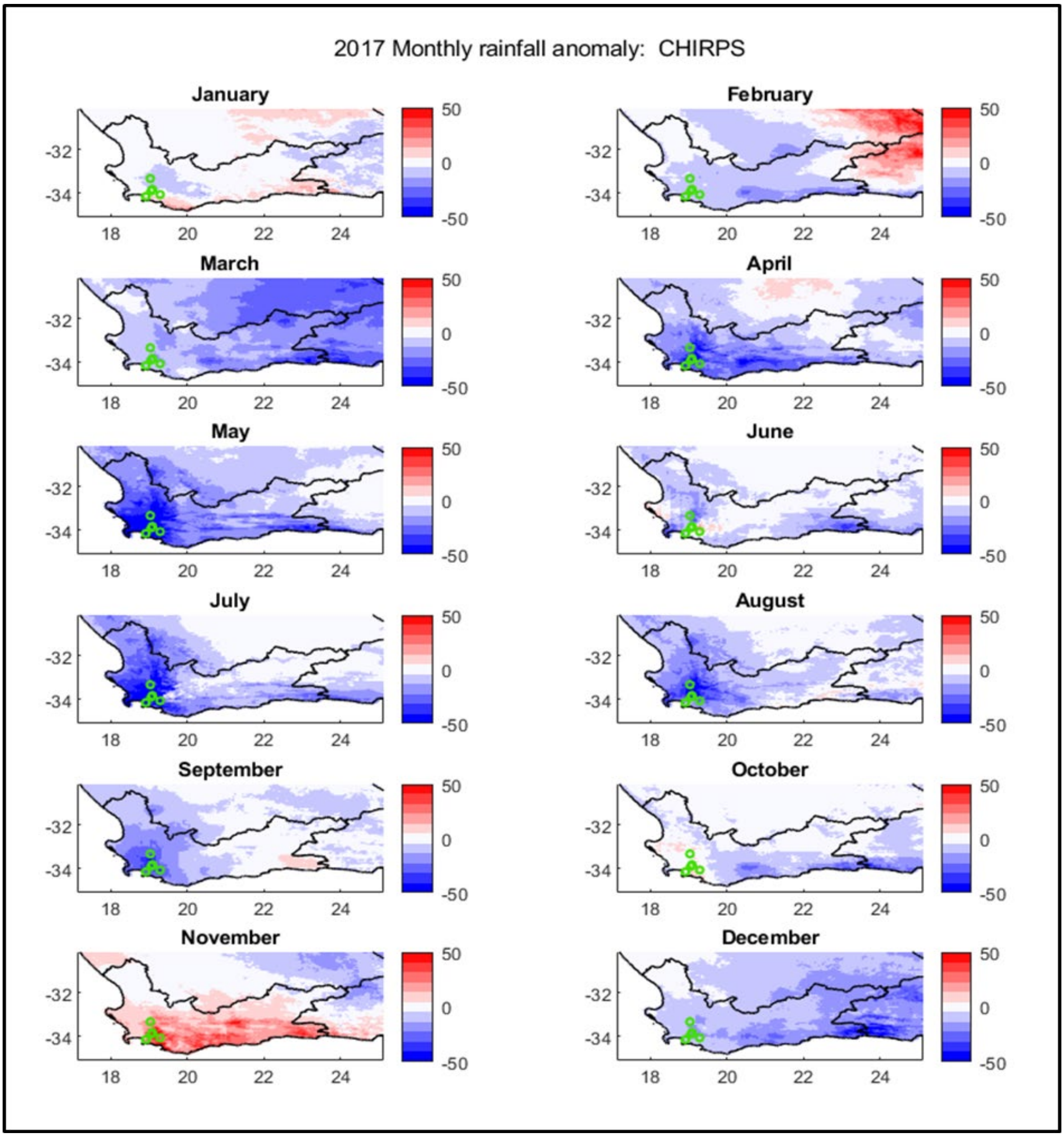

Figure 6: Observed monthly rainfall anomaly for 2016. The location of WCWSS dams are indicated by green circles

4.3 Concluding Remarks

The 2015/16 drought event highlighted the extent to which climatic process can have an impact on water supply. The monthly rainfall anomalies for the three consecutive years starting from 2015 were computed to track the deficit rainfall during the evolution of the 2015/2016 drought event and it showed that the Western Cape received below normal climatic mean rainfall for the 3 consecutive years, with 2017 being the driest. These results agree with the findings by (Burls, 2019) that the severity of the three-year drought in Cape Town is a result of long term decrease in rainfall days and interannual to decadal variability of rainfall.

5 THE IMPACT OF THE 2015/17 DROUGHT IN LANGA TOWNSHIP AND INFORMAL SETTLEMENT

5.1 Background on Langa Township and Informal Settlement

Langa is one of the oldest townships in Cape Town, and it was formed as a result of racial separation and oppression (Boudreaux, 2006). It is situated next to the Cape Town International Airport, and just East of the suburb of Pinelands. It is surrounded by Jan Smuts drive to the west, the N7 road to the east, and the N2 road to the north.

Langa was originally built in the 1930s to house migrant Black workers (Saunders, 1979). Due to it being closer to the city and it is easily accessible through public transport, it has become densely populated by migrant workers (Coetzer, 2009). It has the largest number of Hostels within the city of Cape Town, owing to its historical nature and the manner it was formed.

Langa Township and informal settlement is an interesting place of study to dissect how the 2015/16 drought impacted the township residents within the city of Cape Town in terms of obtaining the Human right and basic needs of water supply during the time of crisis. Langa is also interesting because of the political nature of how it was formed and evolved as an urban African segregated residential township. Just like many Townships around South African cities, it stands out as an authentic testimony of the African struggle to become an integral part of the city. This study seeks to understand how water supply to the residents of Langa was impacted upon during drought, furthermore, it is of paramount importance to get an understanding of how Townships and informal settlements cope during drought events. The researchers seek to understand how the drought has changed water consumption behaviour and how the city intervened during the drought season.

5.2 Residential areas in Langa Township and Informal settlement and their access to water

Langa Township on its own summarises Cape Town’s inequality within its boundaries as demonstrated by its characteristics of the two areas studied in this township: the combination of houses, flats and Hostels (herein referred to as townships), and the shacks of Joe Slovo (herein referred to as informal settlements (Figures 7, 8 and 9).

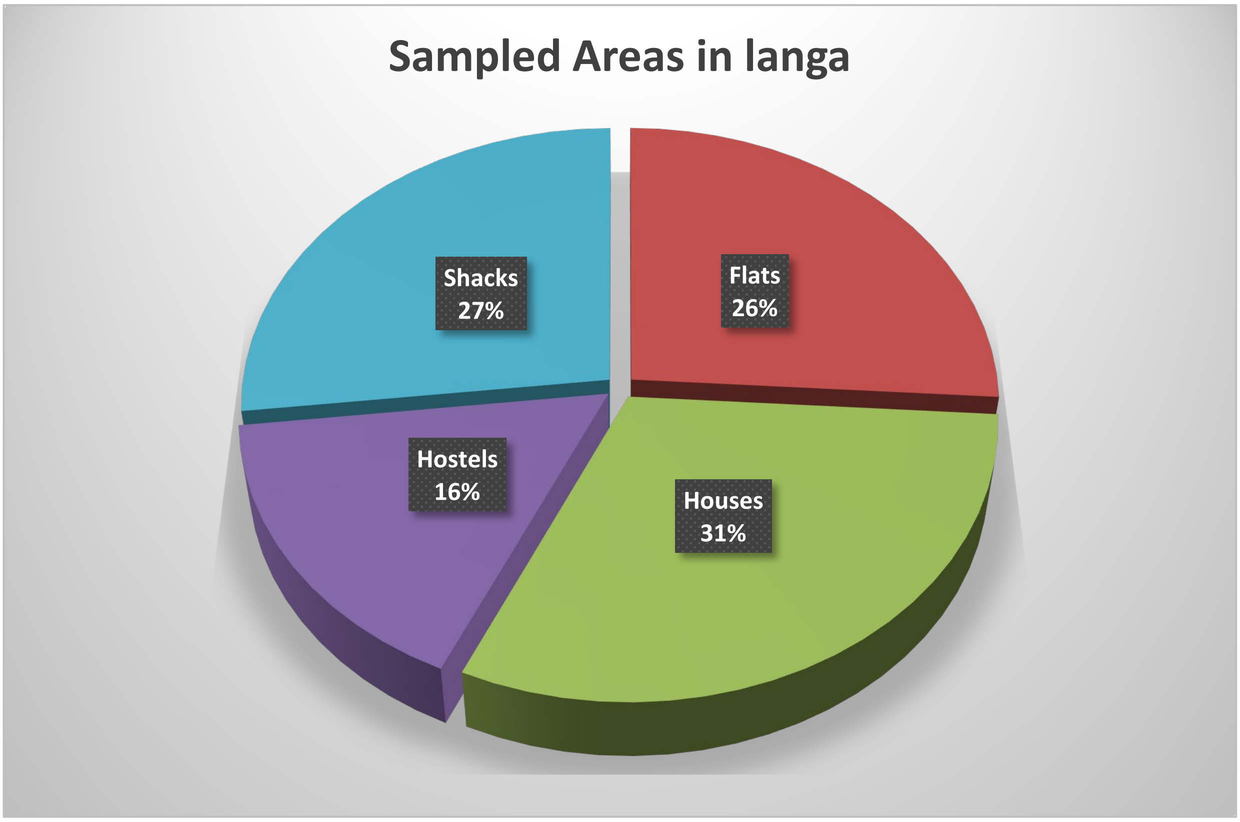

Figure 7: Sampled households and their dwelling types in Langa Township and informal settlement

Figure 8: Newly Built low-cost housing (Flats) at the Langa Formal settlement and the toilet facilities for the shack dwellers in Langa Informal settlement

Figure 9: An unequal scene of Langa residential area as depicted by the standalone houses (township) and the corrugated shacks at the informal settlement

5.3 Communication of the Drought in Langa

Even though the multiyear drought in Cape was known around the world, to most of the informal settlement people it was not as known as it should. The City of Cape Town made great strides to inform its residents and business about the water situation in the province. An entire day zero Campaign was made, posters and flyers were made to guide the citizens and tourist on water shortages in the area and how to save water. However, most of the participants, have revealed that they were not informed by the City of Cape Town about the drought. They only heard about it from Radio and Television. Most of the younger generation stated that they became aware of the water crisis from social media, with most of them stating

Facebook. These go to show that in most cases when there is a disaster the marginalized are not informed of such a crisis.

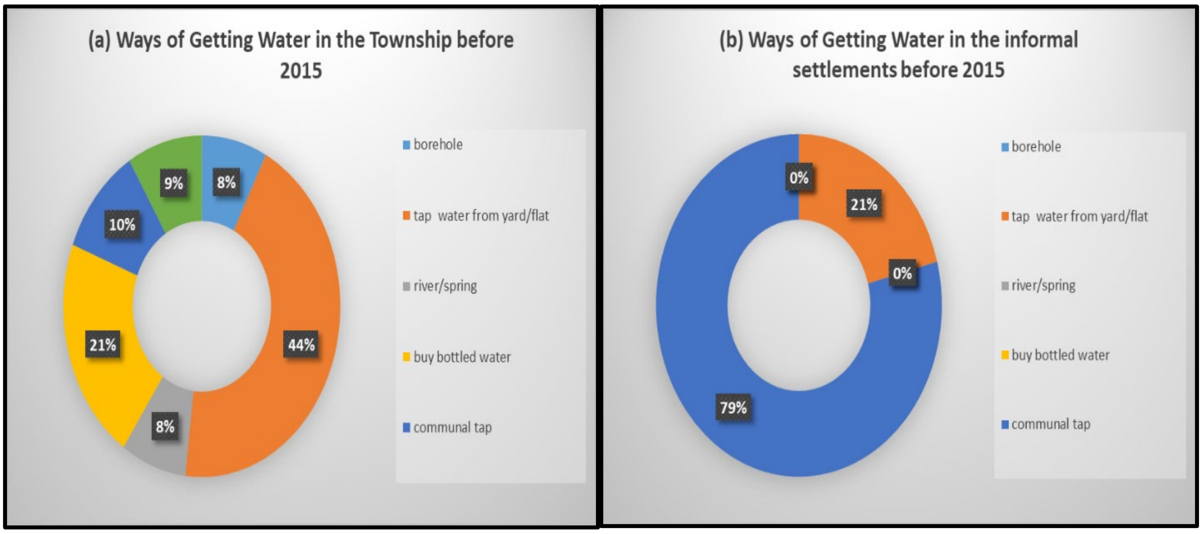

Figure 10: Water collection infrastructure/ways in which people from both (a) township and (b) informal settlements of Langa Area of the City of Cape Town were collecting water before the 2015/16 drought.

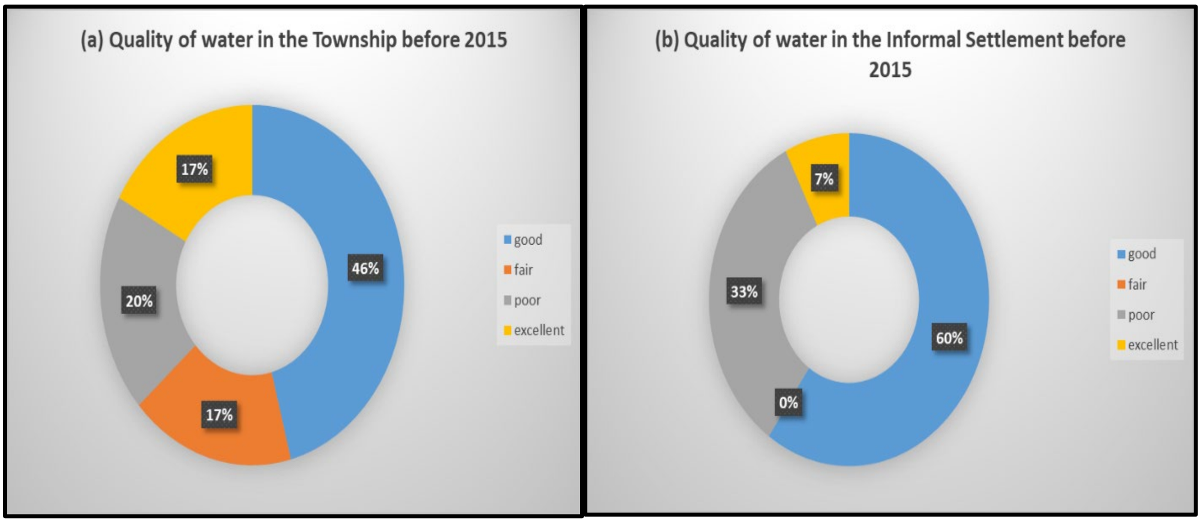

Figure 11: Quality of water received by the people in the (a) township and (b) informal settlements of Langa Area of the City of Cape Town before the 2015/16 drought.

5.4 Water consumption alternatives during 2015/16 Drought.

The other area where surveys were administered is in the informal settlements (Joe Slovo) of Langa, which showed sharp differences in household access to water infrastructure (Figure 11 b). Unlike the residents of Langa township, whereby they enjoyed in-house water connections (Figure 11 a), the Langa informal settlements rely on communal taps for water collections (Figure 11 b) While the city urged people to restrict water usage during the drought, many living in the poor areas already had limited access to water (Figure 12 b). The impacts of water shortages hit unequally. While the middle-class people from Langa Township were able to buy bottled water during the drought (Figure 12 a), poor people from informal settlements who already have fewer water sources were left with only a few options (Figure 12 b).

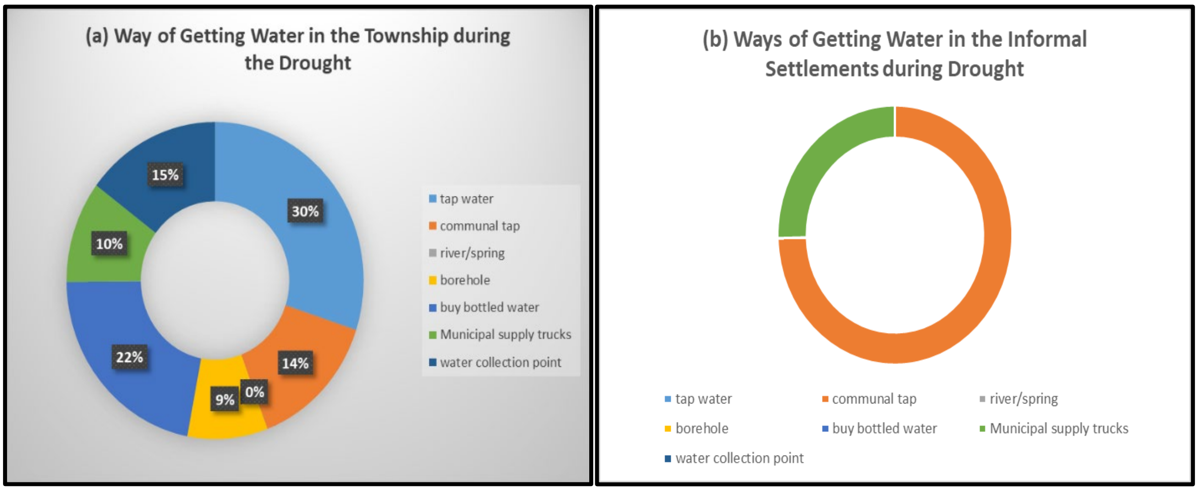

Figure 12: The infrastructure/ways in which people from both the (a) township and (b) informal settlements of Langa Area of the City of Cape Town were collecting water during the 2015/16 drought.

Also, apart from the township residents affording to buy bottled water during the drought, there were other alternative options to collect water in this area, such as collecting water from their in-house taps (whenever water is available), water collection points and communal taps. On the other hand, people living in the informal settlement (shacks) had always collected water from the communal taps, as the water crisis got worse, they had to line up through the night to collect water from the very same taps sharing with some of the people from the middle-class Langa township (Figure 19 a and b) and only a few managed to get access to water at the municipal water collection points. The latter could be a result of many people staying far from these municipal water collection points. Also, the residents in the informal settlements were faced with an extremely high level of stress about how they would manage with even less water.

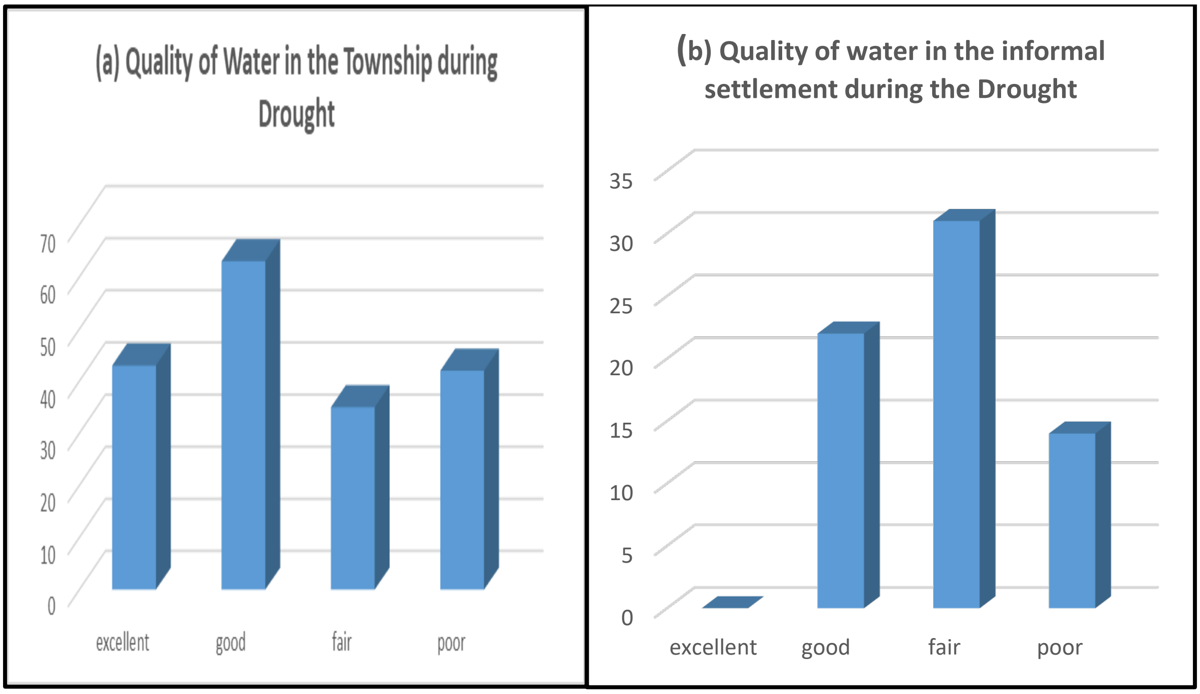

Figure 13: comparison of the water quality as determined by the residents in Langa Township and informal settlement.

Although people living in the informal settlements were still relying on communal tap water during the drought, the quality of that water was rather regarded as fair (Figure 13 a), unlike in the township where the water quality was considered good (Figure 13 b).

5.5 Water conservation mechanisms by Langa residents during and after the drought.

During the drought, the City's dams were drying up, and its residents needed to intensely conserve water remaining supply. Hence, the concept of Day Zero was introduced as a way to startle Cape Town citizens into action. As stated by Ziervogel (2018), the Day Zero concept didn't mean that Cape Town would be left with zero water. It simply implied the day the dams would reach 13.5% capacity. The 13.5% capacity would mean the water is barely enough to keep critical services running. For example, the taps in homes and businesses would be turned off. The residents will have to line up at one of the collection sites to obtain water to drink and bath. Consequently, this water crisis highlighted how bad the inequality is in the area. People in the informal settlements were forced to compromise their right to sanitation and to keep hygiene as they had to bathe less, do laundry less as well as cooking once in a day while residents in the township used extra storages such as buckets to conserve more water. Most of the residents resorted to using greywater.

5.6 Residents recommended Future drought Relief measures to be implemented by the City of Cape Town In Langa

Most of the residents in the informal residents recommended that the City of Cape Town should have communal tanks to provide them with water in such a crisis. They felt that in that way the tanks will provide them much needed relief during the time of crisis. They also indicated the need for the City of Cape Town (municipal officials) to inform them in time and teach them about drought and water-saving strategies. The residents also recommended that the City should bring more communal taps since the taps are far apart and the queues are much longer during the drought. The city resorted to water cuts during the drought popularly known as day zero, and the residents recommended that they should be advised about the schedule of water cuts, more especially the residents in the informal settlement who has to keep on checking the communal stand if the water is coming back. They complained that water was being made available late at night and it does affect their safety. Few of the residents did note that the city needs to build more dams to meet the demand from its residents.

5.7 Concluding remarks

The observed water consumption patterns associated with the 2015/16 drought event resulting from our brief survey at Langa have highlighted a few problems related to communication and water supply associated with drought events. The first problem being the negligence of the authority on information dissemination about consequences of drought on water scarcity in the informal settlements, as evident during the survey when people complained that they were just learning from other community members. The second is the difficulty some households faced in gaining access to alternative water services and ways to conserve the little water they already had. The third is the quality of water they received during the drought event, as witnessed in the township when many participants in our survey made comments about the colour of the water being brownish and the taste not being good in the informal settlements.

6 CONCLUSIONS

The severity of the 3-year drought in Cape Town offers a glimpse of the consequences of climate change in water scarce regions. The year anomalous rainfall analysis has shown that the city of Cape Town has had below normal rainfall during all those three rainy seasons, with 2017 being the driest. Such impact resulted in low water levels in all the dams and the day zero concept crisis. The three-year drought indicated that, drought has a slow onset and its impacts are diverse depending on the readiness of the communities and its ability to cope.

The city of Cape Town is one of the most unequal cities in the world. Such unequal scenes have been clear from the survey which focussed on water supply and consumption during the 2015-17 drought. The difference in the socio-economic class is clear concerning water supply and drought support. The project has uncovered that there is a huge inequality within Townships and Informal settlement. The residents from the township had access to many alternative sources of water during the drought, whereas most of the informal settlement residents had to rely on the communal taps which are widely far apart. The project has also gained insight into behavioural changes on water consumption during the drought. The project team is of the view that The City of Cape Town now has an insight on how they could assist residents when there is a drought or water crisis within Townships and informal settlements. The research team concludes that it is important to ensure that the burden of saving water does not disproportionately affect indigent households and that the government continues to prioritise improvement of the level of services and water specifically in underserved households living in informal settlements or backyard shacks

Following from the research findings is an attempt to discover how the living experiences of the Langa residents inspired them on changing water use patterns and behaviour. Although the proposed research responds to the challenges in Langa Township and Informal Settlement these challenges and the proposed interventions gathered on this research are common to other Townships and informal settlements in South African cities, hence the methods and lessons from this project study are transferable to other areas.

7 RECOMMENDATIONS

Following the insights from the field survey in Langa Township and informal settlement on how the drought-affected the residents, the following actions are recommended.

- *Water use conservation education should remain a priority for people of all socio-economic backgrounds* – it was clear from the survey done that most residents in Langa Informal settlement are yearning to be taught about water conservation and drought preparedness. They have indicated that they were not informed about the 2015-2017 drought and they recommended that the government (City of Cape Town) should inform them about drought. The message of saving water and day zero was much more visible and common in the city centre and affluent suburbs, hence, the message should be taught to the marginalized communities and it should not only be during the drought event but an everyday process.

- *Flexible water and disaster response strategy* – a one size fits all strategy to deal with a crisis does not work in cities with high inequalities – Most residents in informal settlement claim that they had only one source of water during the drought, i.e. the communal tap. They have recommended the city to provide them with water storage facilities such as basic communal tanks since water supply trucks were not operating in their place of residence. Residents in The Township received assistance through designated water collection points and water supply trucks.

- *Collaboration between different sectors of government and departments is needed* – it is of paramount importance that different levels of government (national, provincial, and Local) communicate and work together towards water supply planning and coordinating. The co-operation between these departments should occur at all times, rather than only when there is a crisis.

8 LIST OF REFERENCES

Ballard C. 1986. Drought and Economic Distress: South Africa in the 1800s*. The journal of interdisciplinary History.* **17** (2) 359-378.

Behera SK, Yamagata T.2001. Subtropical SST dipole events in the southern Indian ocean. *Geophysical Research Letters*, **28**(2) 327-330.

Boko M and Co-authors 2007: Africa. Climate change 2007: Impacts, Adaptation and vulnerability, M L Parry et al., Eds, *Cambridge University Press*, 433-4676.

Bordi I, Sutera A .2007*. Drought monitoring and forecasting at large scale*. In Rossi, G., Vega, T. and Bonaccorso, B. (Eds.), Methods and Tools for Drought Analysis and Management. *Springer*, Netherlands, p.3-27.

Botai CM, Botai OJ, Adeola AM. 2018. A Spatial distribution of temporal precipitation contrasts in South Africa. *South African Journal of Science* **114** (7/8) DOI: 10.17159/sajs.2018/20170391

Boudreaux K. 2006. The effects of property titling in Langa Township, South Africa. *Mercatus Policy series comment no 4.* https://ssrn.com/abstract=1027012

Burls NJ, Blamey RC, Cash BA. et al*.* 2019 The Cape Town “Day Zero” drought and Hadley cell expansion. *npj Clim Atmos Sci* **2** **(27**). https://doi.org/10.1038/s41612-019-0084-6

Coetzer N. 2009. Langa Township In the 1920s – an (extra) ordinary Garden Suburb. *SAJAH.* **24**(1) pp. 1-19. ISSN 0258-3542.

City of Cape Town.2018. Amended Level 5 water restriction guidelines. 1-3. https://www.news24.com/SouthAfrica/News/city-of-cape-town-relaxes-waterrestrictions-tariffs-to-level-5-20180910

Dai A.2011b. Drought under global warming: A review. *Wiley Interdisciplinary Reviews: Clim. Change* **2**, 45-65

Das HP.2012. Agrometeorology in extreme events and natural disasters. *BS Publications*. India. 600 pp.

Dennis I, Dennis R .2012. Climate change vulnerability index for South African aquifers. *Water SA* **38** 417-426.

Diersen MA, Taylor G. 2003. Examining economic impact and recovery in South Dakota from the 2002 drought. *South Dakota State University*, Brookings, South Dakota.

Disaster Management Act, Government Gazette, Republic of South Africa. 2002. http://www.info.gov.za/gazette/acts/2002/a57-02

Dodson B. 2003. "Above Politics? Soil Conservation in 1940s South Africa." Workshop on South Africa in the 1940s, Southern African Research Centre. http://www.queensu.ca/sarc/Conferences/1940s/Dodson.

Dieppois B, Rouault M, New M. 2015. The impact of ENSO on Southern African rainfall in CMIP5. *Climate Dynamics*. **45** 2425-2442.

Engelbrecht CJ, Engelbrecht FA. 2015. Shifts in Köppen-Geiger climate zones over southern Africa in relation to key global temperature goals. *Theor. Appl. Climatol.*, doi: 10.1007/s00704-014-1354-1.

Engelbrecht FA, McGregor JL, Engelbrecht CJ. 2009. Dynamics of the Conformal-Cubic Atmospheric Model projected climate-change signal over southern Africa. *R. Meteorol. Soc.* **29** 1013-1033. http://dx.doi.org/10.1002/joc.1742.

Engelbrecht FA, Landman WA, Engelbrecht CJ , Landman S, Bopape MM, Roux B, McGregor JL, Thatcher M. 2011: Multi-scale climate modelling over southern Africa using the variable-resolution global model, *Water SA, **37***, 647-658.

Engelbrecht F, Adegoke J, Bopape M, Naidoo M, Garland R. Thatcher M, McGregor J, Katzfey J, Werner M.2015.. Projections of rapidly rising surface temperatures over Africa under low mitigation. *Environmental Research Letters*. **10**(8): 85004. DOI: 10.1088/1748-9326/10/8/085004.

Fraisse CW, Gelcer EM, Woli P. 2011. *Drought Decision-Support Tools: Introducing the Agricultural Reference Index for Drought—ARID1*. Report No. AE469. Institute of Food and Agricultural Sciences, University of Florida, 5 pp. Available at: http://www.aces.edu/climate/documents/DDST-IntroAgRefIndexDrought-ARID.pdf

Funk C, Peterson P, Landsfeld M, Pedreros D, Verdin J, Shukla S, Husak G, Rowland J, Harrison L, Hoell A, Michaelsen J. 2015a The climate hazards group infrared precipitation with stations - A new environmental record for monitoring extremes. *Scientific Data*. **2** 150066. https://doi.org/10.1038/sdata.2015.66.

http://www.csag.uct.ac.za/2019/03/12/what-is-city-relevant-climate-information-and-how-can-it-be-used/

Hassan R. 2013 Drought Management Strategies in South Africa and the Potential for Economic Policy Instruments. In: Schwabe K et al. (eds) Drought in Arid and Semi-Arid Regions Springer Science and business Media Dordrecht. https://doi.org/10.1007/978-94-007-6636-5_21

Hayes MJ, Svoboda MD, Wardlow BD, Anderson MC, Kogan F. 2012. Drought monitoring: historical and current perspectives. In: *Remote sensing of drought, innovative monitoring approaches* [Wardlow, B.D., Anderson, M.C. and Verdin, J.P. (eds.)] CRC Press, Boca Raton, USA

Heim RR Jr. 2002. A review of Twentieth-Century drought indices used in the United States. *Bull. Amer. Met. Soc.* **83** 1149-1165

Holloway A .2000. Drought emergency, yes…drought disaster, no: Southern Africa 1991-93. *Cambridge review of International Affairs* **14**(1) 254-276. https://doi.org/10.1080/09557570008400341

Howden M, Schroeter S, Crimp S and Hanigan I. 2014. The changing roles of science in managing droughts: An Agricultural perspective. *Weather and Climate Extremes* **3** 80-89.

http://web1.capetown.gov.za/web1/OpenDataPortal/

Jury MR, Mwafulirwa ND. 2002. Climate variability in Malawi, Part I: Dry summers, statistical associations and predictability. *Int. J. Climatol.* **22** 1289-1302

Kruger AC, Shongwe S. 2004. Temperature trends in South Africa: 1960-2003. *International Journal of Climatology*. **24** 1929-1949. DOI: 10.1002/joc.1096.

Matikinca P, Ziervogel G, Enqvist JP.2020. Drought response impacts on household water use practices in Cape Town, South Africa. *Water Policy* **22**(3) 483-500. https://doi.org/10.2166/wp.2020.169

McGregor JL. 2005. C-CAM: Geometric aspects and dynamical formulation. CSIRO Atmospheric Research Tech. Paper No 70, 43 pp

Otto FEL, Wolski P, Lehner F, Tebaldi C, Jan van Oldenborgh G, Hogesteeger S, Singh R, Holden P, Fuckar NS, Odoulami RC, New M. 2019. Anthropogenic influence on the drivers of the Western Cape drought 2015-2017. *Environmental Research Letters* **13** 124010. https://doi.org/10.1088/1748-9326/aae9f9

Naik M, Abiodun BJ. 2020. Projected changes in drought characteristics over the Western Cape, South Africa. *Meteorological Applications* 1-14. https://doi.org/10.1002/met.1802

National Department of Agriculture .2005. Drought Management Plan, A Discussion Document for the public.

O'Meagher B, Du Pisani LG, White DH. 1998. Evolution of Drought Policy and related Science in Australia and South Africa. *Agricultural Systems* **57**(3) 231-258.

Reason C J C and Rouault M 2005. Links between the Antarctic Oscillation and winter rainfall over southwestern South Africa. Geophysical Research Letters. 32(7).doi:10.1029/2005GL022419.

Saunders C .1979. The creation of Ndabeni: Urban segregation and African resistance in Cape Town. *Studies in the History of Cape Town vol 1.*

SADCC .1992. Food security bulletin, SDCC, Gaborone, Botswana.

Sillmann J, Kharin VV, Zhang X, Zwiers FW, Bronaugh D. 2013. Climate extremes indices in the CMPI5 multimodel ensemble: Part 1. Model evaluation in the present climate, *J. Geophys. Res. Atmos*. **118** 1716-1733, doi:10.1002/jgrd.50203

Simpkins G. 2018. Running dry. *Nat. Change* **8** 369-369.

Sinclair-Smith K , Winter K. 2018. Water demand management in Cape Town: Managing water security in a changing climate In Scott D, New M and Davies H (eds). Climate Change and urban Developments: lessons from Cape Town. UCT Press

Smakhtin VU, Hughes DA. 2004. Review, automated estimation and analysis of drought indices in South Africa. Working paper 83. Colombo, Sri Lanka: International Water Management Institute, 24 pp.

Smith L, Hanson S .2003. Access to Water for the Urban Poor in Cape Town: Where Equity Meets Cost Recovery. *Urban Studies*. **40** 1517-1548.

Sorensen P. 2017 The chronic water shortage in Cape Town and survival strategies. *International Journal of Environmental Studies*. **74**(4) 515-527. https://doi.org/10.1080/00207233.2017.1335019

Stringer LC, Dyer JC, Reed MS, Dougil AJ, Twyman C, Mkwambisi D. 2009. Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. *Environmental Science and Policy*. **12**(7) 748-765.

Sun L .2009. Blended drought indices for agricultural drought risk assessment on the Canadian Prairies. M.Sc. thesis, Carleton University, Canada, p.1-163.

Taing L, Chang CC, Pan S, Armitage NP. 2019. Towards a water secure future: reflections on Cape Town's Day Zero crisis. *Urban Water Journal* **16**(7). https://doi.org/10.1080/1573062X.2019.1669190

Tallaksen LM, van Lanen HAJ. 2004. Introduction. In: Hydrological drought: processes and estimation methods for streamflow and groundwater [Tallaksen, L.M. and H.A.J. van Lanen (eds.)], *Elsevier, Amsterdam 579 pp.*

UNISDR (United Nations International Strategy for Disaster Reduction), (2006). Global Survey of Early Warning Systems, 46 pp. Available at: http://www.unisdr.org/files/3612_GlobalSurveyofEarlyWarningSystems.pdf

Van Zyl K. 2006: A Study on a Disaster Risk Management Plan for the South African Agricultural Sector, Assigned by Agri SA, NAFU SA and TAU SA, Funded by Total SA, Pretoria.

Vogel C.1994. The impact of extreme drought events. *Report submitted to the HSRC Human Needs, Resources and the Environment Programme supported by the Department of Environment Affairs*

Vogel C H 1994a. (Mis) management of droughts in South Africa: past, present and future. *South African journal of Science*. **90** 4-6

Vogel CH 1994c: Consequences of droughts in southern Africa (1960-1192) unpublished PhD thesis, university of the Witwatersrand, Johannesburg.

Vogel C. 2000. Climate and climatic change: causes and consequences. In: *The geography of South Africa in a changing world* [Fox, R. and K. Rowntree (eds.)], *Oxford University Press, Cape Town, 509 pp*

Vogel CH, Drummond JH.1993. Dimensions of Drought: South African Case studies. *South African Geography and post-Apartheid Reconstruction.* 93-98 https://www.jstor.org/stable/41145720

Vogel C, Koch I, Van Zyl K. 2009 "A persistent Truth"-Reflections on drought Risk Management in Southern Africa. *Weather, Climate and Society*. **(2)** 9-22.

Vogel CH, Laing M, Monnik K. 2000. Drought in South Africa, with special reference to the 1980-94 period. In Wilhite DA (ed) Drought volume 2 A global assessment, Routledge, London, pp 348-367.

Wilhite D, Buchaman-smith M .2005. Drought and water crises: Drought lessons learned and the road ahead. In: Wilhite D (ed) drought and water crisis. Taylor and Francis, pp 389-398.

Wilhite DA, Sivakumar MVK, Pulwarty R. 2014. Managing Drought risk in a changing climate: The role of national drought policy. *Weather and Climate Extremes*. **3** 4-13. https://doi.org/10.1016/j.wace.2014.01.002

Wilhite DA, Svoboda MD, Hayes MJ. 2007. Understanding the complex impacts of drought: A key to enhancing drought mitigation and preparedness. *Water Resour. Manage.,* **21**, 763-774

Wolski P.2018. How severe is Cape Town's "Day Zero" drought? *Significance* **15**, 24-27

http://web1.capetown.gov.za/web1/OpenDataPortal/

Ziervogel G. 2018. Climate adaptation and water scarcity in southern Africa. *Current History.* **117** 181-186.

APPENDIX:

SURVEY

- Study area:
  - Langa Township and informal settlements
  - Wynberg

(i)What is your place residence?

a) Suburb
b) Informal settlement
c) Township

1. Under normal circumstances, how do you get drinking water?
a) Tap water in house or yard
b) Communal tap
c) River/spring
d) Borehole
e) Buy bottled water
f) Other (specify) ____

2. How would you rate the quality of your drinking water?
a) Excellent
b) Good
c) Fair
d) Poor
Comment:
____
____

---

3. During the 2015/16 drought event, how did you get drinking water?
a) Tap water in house or yard
b) Communal tap
c) River/spring
d) Borehole
e) Buy bottled water
f) Municipal supply trucks
g) Water collection point

4. How would you rate the quality of your drinking water during the 2015/16 drought?
a) Excellent
b) Good
c) Fair
d) Poor

Comment: ____

5. Since the 2015/16, did you do anything to conserve water at home indoors and outdoors? a)Yes
b) No
If yes, how?____
____
____

6. How did you find out about the 2015/16 drought?
a) Local forum networks
b) Social media/Radio/TV
c) other (Please specify)
____

7. Who do you think is responsible for keeping you informed about drought updates?
a) Social media/News/Newspaper
b) City of Cape Town
c) Other (Please specify)
____

8. Should drought occur again, what can you do differently?

9. Should drought occur again, what can the City of Cape Town do differently?